

TOWN OF EDSON
GEOTHERMAL PILOT PROJECT
FEASIBILITY STUDY
FINAL REPORT

PREPARED FOR:

Renewable Energy Branch
Energy, Mines and Resources Canada
Ottawa, Canada
DSS Contract File No: 51SZ 23216-6-6281
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Feasibility Study - Final Report

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OBJECTIVES: To investigate the feasibility of utilizing an
existing abandoned or suspended oil or gas
exploration well or wells and an existing suitable
heating load to develop a low cost geothermal
heating demonstration project for the advancement
of geothermal energy technology, economics and
development in Canada.

RESULTS: Capital costs for the conceptual system are estimated at \$1,273,000, with net annual operation and maintenance costs estimated at \$38,700.00. Estimated costs for a recommended well preparation and pump testing program are \$175,000 for a single existing well, or \$314,000 for a pair of existing wells for supply and disposal.

CONCLUSION: Use of existing abandoned wells from oil and gas exploration activities may result in economics in developing a pilot or full scale geothermal project.

**RECOMMENDATIONS/
COMMENTS:** It is recommended that a well pump testing program proceed as the next step in determining the viability of a geothermal pilot project.

ACKNOWLEDGMENTS

We acknowledge with thanks, the assistance of staff members of the Town of Edson in providing information pertinent to this study, such as heating cost records, and other information and assistance.

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PREFACE

This report outlines the findings of a geological and engineering study of the technical and economic feasibility of making use of existing abandoned or suspended oil and gas exploration wells in the immediate Town of Edson area of Alberta in a geothermal heating demonstration pilot project. The purpose of this study is to advance the technology, economics and development of geothermal energy in Canada in keeping with the Solar Energy Development Program of Energy, Mines and Resources, Canada (EMR), the funding agency. This study follows as a next step and as a recommendation of an earlier study into the feasibility of the use of geothermal energy to heat large buildings in Edson. In addition to the intent of serving the interests of the Town of Edson and EMR, this report may be of interest to other municipalities, groups, agencies or private industry interested in the use or development of a geothermal energy resource.

ABSTRACT

The objective of this study was to investigate the feasibility of utilizing an existing abandoned or suspended oil or gas exploration well and an existing suitable heating load to develop a low cost geothermal heating demonstration pilot project in the immediate Town of Edson area of Alberta.

A reservoir analysis of the potential geothermal production formation and an update of the inventory of existing wells were carried out using well drilling logs, drill stem tests and other pertinent information from exploration wells drilled in the area, in order to define a suitable geothermal aquifer source and wells for this project.

Capital and operating cost estimates and a cost/benefit analysis based on the value of natural gas heating energy displaced were carried out for the conceptual pilot project system.

Capital costs for the conceptual system, including well testing, were estimated at \$1,273,000. A significant portion of this cost is associated with the excessive distance between the only suitable existing pair of wells presently available for this project. It was suggested that other more suitably located wells may become available in future to substantially reduce the cost.

It was found that information available from oil and gas well exploration activity is useful in assessing geothermal potential and defining certain system design parameters and limitations, and that the use of existing abandoned wells from this activity may, under the right conditions, result in economies in developing a pilot or full scale geothermal system.

It was recommended that a well pump testing program proceed as the next step in determining the viability a geothermal pilot project.

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LIST OF ABBREVIATIONS AND SYMBOLS

a	- annum or year
cap	- capita
°C	- degrees Celsius
cm	- centimetre(s)
d	- day
GJ	- gigajoule(s)
ha	- hectare(s)
h	- hour(s)
I.D.	- inside (pipe) diameter
kg	- kilogram
kJ	- kilojoule(s)
km	- kilometre(s)
kPa	- kilopascal(s)
KV	- kilovolt(s)
kW	- kilowatt(s)
L	- litre(s)
m	- metre(s)
m ²	- square metre(s)
m ³	- cubic metre(s)
mg	- milligram(s)
min	- minute(s)
mL	- millilitre(s)
mm	- millimetre(s)
O.D.	- outside (pipe) diameter
s	- second(s)
W	- watts

METRIC-IMPERIAL CONVERSION TABLE

1°C	= 1.80 °F
1 GJ	= 947,230 BTU
1 ha	= 2.471 acre
1 km	= 0.6214 miles
1 kJ	= 0.9472 BTU
1 kPa	= 0.1450 psi
1 kW	= 1.341 hp (mechanical)
	= 1.340 hp (electrical)
	= 3.412 BTU/hr.
1 L	= 0.2200 Imp. gal
1 L/s	= 13.20 Imp. gal/min
1 m	= 3.281 ft.
1 m ²	= 10.76 ft. ²
1 m ³	= 35.31 ft. ³
1 mm	= 0.03937 inch

EXECUTIVE SUMMARY

A feasibility study in the use of geothermal energy to heat large facilities in Edson, Alberta, was completed in July 1985. As found in that study, there is reason to believe that the economic viability of a commercial geothermal project in Edson will improve with increasing costs of fossil fuels and improved technology in geothermal heat recovery and pumping. This study has therefore been carried out as a recommendation of the earlier study, to develop a small scale geothermal heating pilot project, possibly, (for reasons of cost savings), involving the use of an existing abandoned exploration well or wells, for the purpose of advancement of geothermal energy technology and economics in Canada.

A reservoir study was conducted using well logs, drill stem tests, production information and other data from 50 wells in the study area in order to identify, map and determine the geothermal potential of water-bearing reservoirs or pools of the Belly River Formation within a two kilometer radius of the Town of Edson. The Belly River Group extends approximately from the 1300 m depth to the 1600 m depth in the Edson area. An updated inventory and status of existing wells within the study area was also carried out in order to determine those which are abandoned or suspended and their suitability for conversion to geothermal use. Two existing available wells for the geothermal pilot project were identified and a well testing program outlined.

Existing heating loads within the study area were investigated in order to find one of adequately large size, low temperature and suitable location for the low temperature geothermal pilot system.

Capital and operating cost estimates and a cost/benefit analysis of the conceptual geothermal heating pilot system and well testing program were carried out.

The reservoir analysis showed that there are separate and isolated reservoirs or pools within the Belly River sandstones which would be of adequate porosity and therefore of adequate permeability to serve as geothermal aquifers. In order to achieve sustained production from any one or all of these isolated pools it is necessary to establish a cyclic system, involving injection of water into the pool from which it is being produced.

Because of the limited number of existing abandoned or suspended wells within the immediate Edson area, and the requirement that a pair of wells or "doublet" be found within the same pool, only one pair of potentially suitable available existing wells was found, at a 3.7 km spacing between wells, which is significantly greater than the "optimal" of approximately 1 km considering life expectancy and cost of interconnection.

Cost of a new well would be in the same order of magnitude as the cost of the additional length of pipeline between the existing pair of wells, and therefore the capital on operating cost and cost/benefit analysis was carried out based on a system concept utilizing the existing wells.

The heating load identified as being suitable for the geothermal pilot system is the heating of the Town's municipal water system and therefore the cost/benefit analysis was also based on a system concept utilizing this heating load.

Estimated total capital cost for the geothermal heating system pilot project and well testing program is \$1,273,000, with an estimated total annual operation and maintenance cost of \$44,700 not allowing for capital amortization, nor for the estimated \$6,000 annual cost saving as a result of displacement of natural gas energy use for the Town's municipal water supply system.

A significant capital cost item in this analysis is the estimated \$504,000 cost of the 5,600 m well-to-well piping associated with the only two potential abandoned wells presently available for this project, or the approximate equivalent cost of drilling a new well for this purpose.

Additional existing wells may become available in future, so that a more cost effectively located and suitable pair of existing abandoned wells may be used in the future to result in perhaps a saving in the order of \$450,000 for the geothermal pilot heating system. Also suitable additional or increased heating loads may become available in future, resulting in a less costly system to operate.

It is recommended that either; a single (existing) supply well preparation and testing program as described herein at an estimated total cost of \$175,000, or a combined (existing) supply and disposal well preparation and testing program as described herein at an estimated total cost of \$314,000, proceed as the next step in the development of a geothermal pilot project to prove up long term capability, characteristics and suitability of the supply well, disposal well and aquifer formation as a geothermal source for the pilot project.

It is also recommended that the status of oil and gas wells and potential low temperature heating loads in the immediate Edson area be monitored on a regular basis, with the objective of obtaining a more cost effectively located and suitable pair of existing abandoned wells and heating load(s) for use in a minimal cost geothermal heating pilot project, for purposes of advancement of geothermal energy technology, economics and development in Canada.

It is also recommended that the Town of Edson be advised in advance of all abandonment plans for existing wells in the immediate Edson area in future, so that they may take steps to avoid well abandonment procedures that may reduce the adaptability of such wells for conversion to geothermal use.

RESUME

(Executive Summary to be translated by EMR).

INTRODUCTION

A Feasibility Study in the Use of Geothermal Energy to Heat Large Facilities (Contract No. 1SQ84-00138)³ was carried out by UMA Engineering Ltd. on behalf of the Town of Edson for Energy Mines and Resources Canada, in July 1985. The study examined the technical and economic feasibility of pumping low temperature geothermal water from deep wells, removing the energy by heat exchangers, and using the energy to heat a series of large buildings.

A detailed assessment of geothermal resources in the Edson area was completed using available published research reports and 235 well records from oil and gas exploration in the immediate area. Two potential aquifers were identified - the Belly River Formation at a depth of 1500 m with water temperatures in the 45°C range and the Beaverhill Formation at a depth of 3500 metres with temperatures in the 100°C range.

A number of models were developed to assess the economics of using the lower and higher temperature sources to heat existing and future buildings in the town.

It was concluded that development of low temperature geothermal heating systems in Edson is technically feasible. A full scale low temperature (45°C) geothermal heating system consisting of supply and disposal wells, heat exchangers and distribution systems would cost in the order of \$3 million (1985). A corresponding higher temperature (100°C) system would cost in the order of \$12 million (1985).

The lower temperature system would operate at a modest loss while the higher temperature system would operate at a modest cost saving relative to conventional gas heating, without considering repayment of capital.

While it is evident from this study that such systems are not commercially viable at this time there is reason to believe the situation will improve. The economics will be more favourable with increasing costs of fossil fuels, and improved technology in pumping and heat recovery. Based on discussions with local drilling contractors, there is also reason to believe that water temperatures may be somewhat higher at shallower depths than indicated by data available for the initial study. Higher temperatures will further improve the economics.

During the course of the study it became evident that an operational system was required to produce technical and economic data on low temperature, high salinity geothermal systems. Because of the large amount of oil and gas exploration in the Edson area, there is a better than average data base on the geothermal resources. Additionally there is the possibility of accessing cased abandoned exploration wells to conduct testing and developing these wells into production and disposal wells.

Considering the potential for geothermal resource exploitation and the high cost of full prototype systems, a small scale pilot project possibly involving the use of an abandoned exploration well or wells appears to be the logical next step in advancement of a geothermal energy project.

While there is widespread use of high temperature geothermal energy systems throughout the world, there is little hard data on the economics and technicalities of using low temperature geothermal resources available in Canada. Operating systems are required to provide experience on:

- design
- operations/maintenance
- capital cost
- operating costs

of low temperature systems in general, and pumping and heat exchange components in specific.

Because of the high cost of large, full scale prototype systems that maximize the energy from the source wells, a small pilot project using existing abandoned wells offers the opportunity of a relatively low cost research facility.

This feasibility study has thus been carried out to develop such a pilot project, specifically to identify a suitable wells and suitable energy user, and to develop the conceptual design and cost of the complete system.

2.0 OBJECTIVES

The objectives of this study are summarized as follows:

- to identify a specific geothermal energy source for a pilot project, either preferably an abandoned exploration well or a new well

- to develop a plan and cost estimate for drilling out or drilling of the well, to do pump tests to prove up temperatures, flow rates, salinities and disposal requirements for the geothermal water
- to identify and incorporate where possible the most recent and innovative technology in pumping and heat recovery
- to develop the conceptual design of the pilot project including supply well, heat exchanger, distribution system to a single user, and disposal of the geothermal water
- to develop capital and operating costs of the proposed system.

3.0 METHOD

The method of carrying out this study is outlined as follows:

- An updated inventory of existing oil and gas exploration wells within 2 km of Town boundaries was assembled by researching ERCB records and consulting with local drilling contractors; abandoned wells were identified and those most suitable for re-entry were determined.
- A short list of available alternative geothermal sources was developed - including locations depths, temperatures, type of casing and plugs, of existing wells. The possibility of a new geothermal well was also investigated.

- A detailed assessment of the reservoirs within the Upper Cretaceous Belly River Group, over a six mile by six mile block centered on the town of Edson was conducted using well logs, drill stem tests, production data and other pertinent information from 50 wells within the 6 mile by six mile block to determine the number and extent of water-bearing Belly River reservoirs or pools within a two kilometre radius of the Town of Edson.
- Temperatures, flow rates and life expectancy of available energy from the potential geothermal sources were estimated.
- Options for disposal of well test geothermal water such as a separate disposal well or dilution and surface discharge were considered, in addition to disposal of the pilot project geothermal water.
- Regulatory and licensing requirements were identified for conducting a well testing program, and for the geothermal pilot project system.
- Compatible energy users were identified considering existing building heating systems, feasibility of retrofit and available geothermal energy.
- A single geothermal source and user was selected and a conceptual design of a complete system was developed.
- A detailed plan and cost estimate for drilling out, downhole perforating and pump testing an abandoned well and brine disposal was developed. This included consultation with the Town, regulatory agencies such as

the Energy Resources Conservation Board and Alberta Environment and consultation with well drillers, and oil and gas drilling consultants familiar with wells in the Edson area.

- Capital and operating costs for the concept design were developed.
- Based on this work and analyses, conclusions were drawn and recommendations made with respect to future geothermal investigation.

4.0 RESERVOIR ANALYSIS AND EXISTING WELLS INVENTORY

A geological and engineering study of the geothermal energy potential of the upper Cretaceous Belly River formation, extending from a depth of approximately 1300 m to 1600 m below the surface in the Edson area, was carried out by Sproule Associates Ltd. as part of this study. The geological study report is included as Appendix II of this report. The report identifies and maps five water bearing Belly River sandstone zones, designated as "Reservoirs" or "Pools" "A" to "E" and evaluates the geothermal potential of each. The report also contains an updated inventory of wells drilled within a six mile by six mile block centered on the Town of Edson, and from this data, develops a short list of wells within a two kilometer radius of the Town of which may be considered for this project. These wells are as follows:

1. Abandoned (1980) well in LSD 6-14-53-17 W5M - "A" and "D" Pools.
2. Abandoned (1964) well in LSD 4-21-53-17 W5M - "A" and "B" Pools.

3. Abandoned (1972) well in LSD 10-22-53-17 W5M - "D" and "E" Pools.
4. Suspended (1987) well in LSD 10-22-53-17 W5M - "D" and "E" Pools.

A further description of these wells is contained on Page 9 of the Geological Report, and these wells and water bearing reservoirs are plotted on Figure 8 of the Geological Report. These wells are also plotted and identified on Figure "A".

The suspended (1980) Well in LSD 10-18-53-17 W5M is not included in the above list since, in addition to being beyond a 2 km radius, it is a productive gas well and thus not likely available.

All of the above wells, except the abandoned (1972) 10-22 well, have 114 mm (4 1/2") O.D. casing extending substantially below the bottom of the Belly River formation, thus making them considerably less difficult to re-enter than if un-cased. The abandoned (1972) 10-22 well has 245 mm (9 5/8") surface casing to the 366 m depth, but has no casing below that depth, and the surface casing is cut off at 3.7 m below the surface and filled over with concrete. Thus this well is considered unusable for this project.

5.0 PILOT SYSTEM HEATING LOAD SELECTION

Retrofitting conventional normal 20°C space temperature buildings and/or use of heat pumps to utilize this low grade heat would be expensive, as found in the 1985 Feasibility Study, and therefore has not been considered in identifying potential loads for this project.

Two potential loads for this project have been considered. The Sundance Aviation Ltd. Hangars at the Edson airport, with total annual natural gas heating costs in the order of \$2,200 based on 1983 and 1984 utility billings, would be suitable in that the space temperature is normally maintained at less than 15°C.

The two existing Town of Edson water reservoirs at 15th Avenue and 63 Street (in LSD 12-21-53-17 W5M) have a total annual natural gas consumption for water tempering of approximately 2,160 GJ (600,000 KWH) at a total annual cost of approximately \$6,000.

Peak load requirement is estimated to be 500 KW. Water recirculation pumps in the valve houses circulate water between the gas fired water heaters and the reservoirs to distribute the heat to the reservoirs and then to the water main distribution system to offset distribution line heat loss and maintain the system at the incoming well water temperature of 5°C during late fall, winter and early spring.

This low temperature, relatively large and steady heat load is quite suitable and is the preferred load for this geothermal application. It is also quite easily adapted to geothermal heating by simply adding the geothermal heat exchangers within the existing pump circulation loops to the reservoirs. The exchangers would be valved in parallel with the existing gas fired water heaters, so that either system could be used. The geothermal water interconnecting well loop would be routed to the heat exchangers located within the valve houses.

REGULATORY AND LICENSING REQUIREMENTS

Permits for well testing will be required from Alberta Environment, one for surface water diversion and disposal (if applicable) under the Clean Waters Act, and one for extraction of ground (geothermal) water under the Water Resources Act. A permanent license will eventually be required for extraction of geothermal water on a permanent basis for the pilot system should it proceed. A sample of the application forms for these permits/licenses is included in Appendix I.

Licenses for testing and use of the supply well and for testing and use of the disposal well will also be required from the Alberta Energy Resources Conservation Board which administers the Oil and Gas Conservation Act and Regulations which applies to wells extending more than 150 m below ground surface. A separate approval to dispose within a formation will also be requested.

A record of telephone conversation with ERCB dated March 15, 1985, regarding licensing requirements for pumping and re-injecting geothermal water is also included in Appendix I.

Evidence of integrity of the existing well casings will also be required by ERCB, possibly requiring casing inspection logs. These and other costs including ERCB application have been allowed for in the well preparation and testing cost estimates.

7.0 WELL PREPARATION AND TESTING

7.1 OBJECTIVES OF WELL TESTING

The main objective of the well testing program is to determine the long term capability and characteristics of the well and aquifer as a geothermal source. This includes:

- a) Determining the ground water hydrology characteristics of the well and aquifer, particularly the long term draw down characteristics of the well/aquifer at various pumping rates to quantify flow rate capability and pumping power input requirements.
- b) Determining the production temperature characteristic of the geothermal water source in order to quantify heating capability.
- c) Determining, by sampling methods, the chemical characteristics of the aquifer water, including chemical constituents, total hardness/salinity, and corrosion and scaling characteristics for use in the design of heat recovery and disposal systems.

7.2 WELL PREPARATION FOR TESTING

The selected existing supply and disposal wells will require drilling out to below the prospective geothermal aquifer and downhole perforating at the prospective aquifer level. Drilling out would entail use of a service rig to drill through any existing concrete plugs placed in the abandoned well casing to seal the well.

Down-hole-perforating of the well casing at the prescribed depth is required in order to allow inflow of aquifer water for geothermal well pump testing and for re-injection into the same aquifer at the disposal well. These operations would be carried out using available oil well servicing rig equipment intended for the purpose.

7.3 TEST WELL WATER DISPOSAL

As much as 18,000 m³ of well test water may have to be disposed of based on a 30 day test period. Methods envisaged include:

- a) use of an existing abandoned or disposal well for re-injection;
- b) dilution and disposal to surface drainage course(s). Required dilution rate for the Belly River salinities involved is projected to be 10 parts dilution water to one part formation water.

In the case of a), a temporary surface pipeline strictly for purposes of well testing, or a more permanent buried pipeline that could be used for the possible future pilot project, would have to be installed between the test well and disposal well.

In the case of b), a dilution supply water source would have to be found and a temporary water surface line and temporary surface disposal line placed.

7.4 ARRANGING WELL TESTS

It will be necessary to contract well testing equipment and crews and the necessary apparatus to carry out the well tests. Equipment envisaged includes a service rig, well

test pump and discharge piping, water temperature testing and sampling apparatus, flow and drawdown measurement apparatus, etc. Cost estimates for this work have been included in Section 10.

7.5 TEST ANALYSIS AND REPORT

Well test results will require analysis as to suitability for, and technical and cost implications involved, in the use of the well as a source for the geothermal pilot project. A report should be prepared based on the analysis of the well test results. The well testing report would be used in implementing the geothermal pilot project as the next phase of geothermal development should the well tests show that a pilot project would be feasible.

8.0 SYSTEM SELECTION CONSIDERATIONS

8.1 WELL SELECTION

The following aspects have been considered with respect to selection of a supply and disposal well for the proposed pilot geothermal heating project.

- .1 Because each of the water bearing reservoirs is surrounded and essentially isolated by relatively impervious formations, in order to avoid reservoir depletion, it is necessary to re-inject any geothermal water extracted, back into the same reservoir. Thus the selection must involve a pair of wells and interconnecting pipeline or doublet, the wells penetrating the same reservoir or "pool".

- .2 A desirable "optimal" separation distance between wells of 1 km. This has been determined on the basis of computer modelling studies of the Regina hydrologic conditions². considering comparative aquifer thickness and comparative geothermal pumping rates. A 1 km spacing would seem to indicate an effective geothermal well/aquifer life (to thermal "break-through") in excess of 25 years for the conceptual Edson pilot system (at a continuous pumping rate of 15³/hour).
- .3 Use of one, and if possible two, of the four identified existing available wells to comprise the geothermal "doublet" system, considering that the cost of re-entering an existing cased suitable abandoned or suspended well is considerably less than drilling a new well, as will be discussed in the following sections.
- .4 Proximity of the doublet wells or interconnecting piping to a suitable (preferably reasonably large, steady and relatively low temperature requirement) heating load, such as 15°C or less space heating or water tempering.

8.2 PILOT PROJECT ALTERNATIVES

Taking into account the above well selection and well testing considerations, and referring to the locations of the four identified available existing wells (refer to Figure 8 of the Appendix "A" Report), the following appear to be the only two feasible geothermal heating pilot project alternatives available making use of at least one of the available existing wells. The 6-14 well coupled with the suspended (1987) 10-22 well utilizing Pool "D" or each of

these separately in conjunction with a new well was not considered superior to the following two alternatives because of nonproximity to suitable heating load(s). The suspended (1987) 10-22 well could not be coupled with the 4-21 well because they do not penetrate a common water bearing reservoir or "pool".

The two alternatives considered further are as follows:

- .1 Use of the existing abandoned 1964 well 4-21 together with the existing abandoned 1980 well 6-14 to heat the existing Town water reservoirs (in LSD 12-21-53-17 W5M). Separation distance between supply and disposal wells would be 3.7 km, as compared to the "optimal" 1 km spacing.
- .2 Use of the existing abandoned 1964 well 4-21 and drilling a new well beyond the site of the existing water reservoirs at 1 km distance from the 4-21 well, to heat the existing water reservoirs.

Both alternatives would utilize Pool "A". The significant difference between these two systems is the cost of the interconnection line between the two wells in Alternative 1 versus the cost of the new well in Alternative 2. The estimated capital cost of the 5600 m interconnecting line between wells in Alternative 1 is approximately the same as the estimated \$550,000 cost for the new well casing and head for Alternative 2. The cost of the approximately 800 m long supply and return geothermal lines required between the 4-21 well and the reservoirs in Alternative 1 is offset by the cost of the single 1 km geothermal well interconnecting line required for Alternative 2. Thus the capital costs of the two systems are approximately the same.

WELL TESTING ALTERNATIVES

It would be desirable to carry out well/formation pump testing prior to major capital outlay, such as outlay for the interconnecting lines, for the geothermal pilot project.

Although final well testing of both the supply and disposal wells will eventually be required by extraction and injection simultaneously, as will be discussed further in this section, it is suggested that preliminary pump tests of the prospective 4-21 supply well, only, be carried out as an initial step to prove up certain characteristics such as temperature, salinity, static water level, drawdown characteristics, and other characteristics of the prospective supply well and formation. Although this may result in somewhat higher well testing total costs, it does allow for staging of these costs, and will assist in determining the suitability and certain characteristics of the prospective supply well and formation prior to investing in the preparation of the disposal well.

Since an interconnecting pipeline will not be available at the time of the initial or final well testing, for either alternative it is envisaged that well test water extracted from the 4-21 well would be disposed of by dilution with fresh water from nearby Bench Creek, a distance of approximately 500 m from the 4-21 well, or by dilution with water from the nearest Town distribution line, a distance of less than 300 m. The diluted well test water (approximately 10 parts fresh water to 1 part geothermal well water) would be disposed of into nearby Bench Creek.

As each of the Belly River reservoirs or pools is essentially isolated, it is necessary in the ultimate pilot system to reinject any geothermal water back into the same pool. In order for eventual final well pump testing to be representative of the ultimate system, any water extracted for final testing purposes should similarly also be re-injected or replaced with an equal volume of water back into the same pool. In order to achieve this, while at the same time avoiding or delaying the installation of a long interconnecting disposal line between the two wells until after final well testing, for either alternative, it is recommended that final pump testing of the 4-21 well be carried out by injecting the same quantity of water into the "A" Pool by making use of the only other available existing abandoned well, the 6-14 well, or another more suitable well which penetrates the "A" pool should one become available.

It is envisaged that water for injection purposes during the final well testing be taken from nearby Bench Creek, a distance of less than 300 m from the 6-14 well. In preparation for final well testing, it would be necessary to re-enter the 6-14 well casing to drill out the existing cement plug extending from the 38 m to 50 m depth and to downhole perforate the casing at the "A" pool formation level.

9.0

SYSTEM CONCEPT

Although the well separation distance of 3.7 km is considerably greater than the "optimal" 1 km, Alternative 1, use of existing 4-21 and 6-14 wells is selected as the conceptual system for further analysis. This alternative is selected for the following reasons:

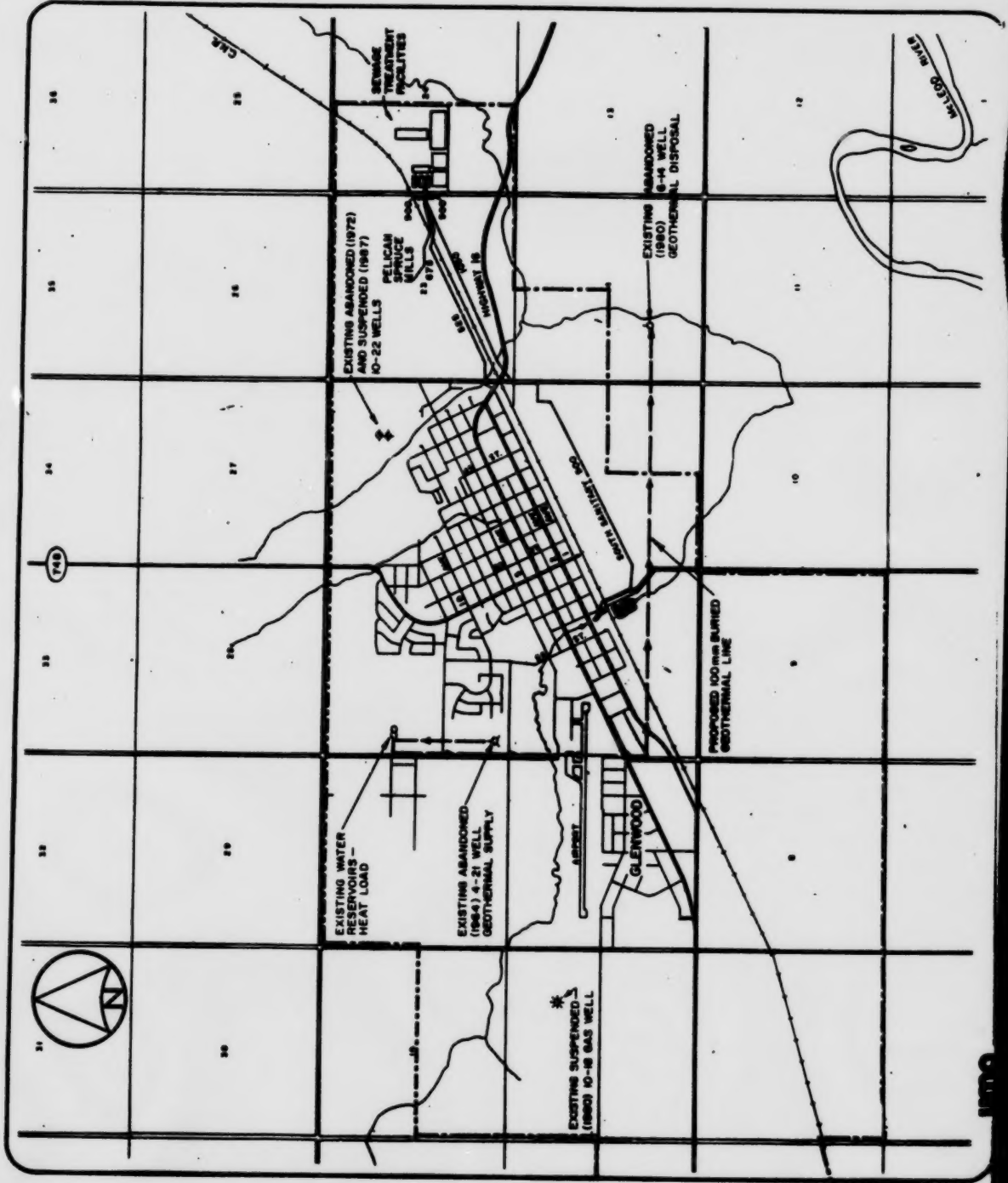
1. Approximately equal total capital costs for well testing and development considering that the cost of reentering, drilling out and downhole perforating of both the existing 4-21 and the 6-14 well is required for either alternative.
2. The same two existing wells that would ultimately be used in the geothermal pilot system in Alternative 1 are currently available for well testing, whereas with Alternative 2 the well testing would not duplicate the identical ultimate geothermal well system configuration, and would thus not be fully representative.

A conceptual layout plan of the system is shown in Figure A and a simplified schematic of the system is shown in Figure B.

TOWN OF EDSON
GEOTHERMAL PILOT
PROJECT
FEASIBILITY STUDY

GEOTHERMAL PILOT
SYSTEM CONCEPT
LAYOUT

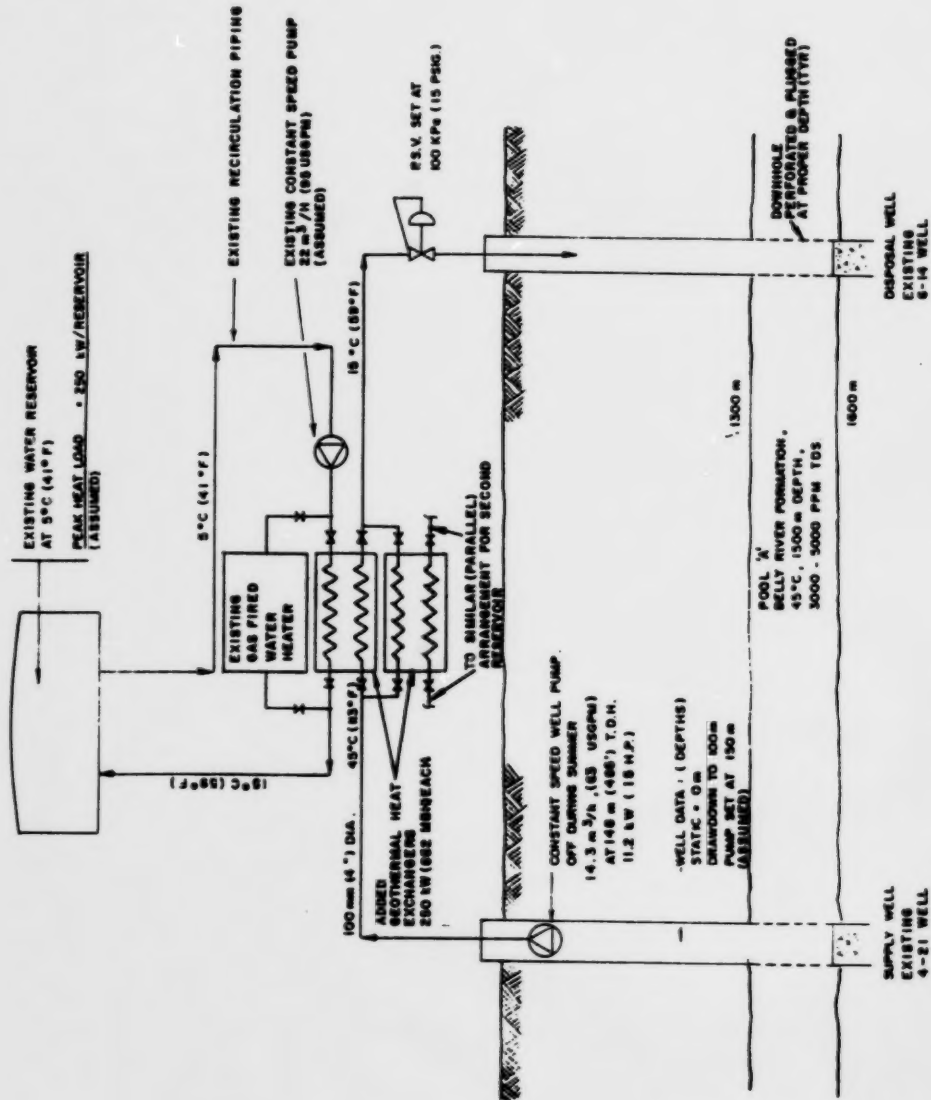
figure 'A'



TOWN OF EDSON
GEOTHERMAL PILOT PROJECT
FEASIBILITY STUDY

SCHEMATIC
GEOTHERMAL PILOT SYSTEM
CONCEPT

UMA



10.0 COST/BENEFIT ANALYSIS

A capital and operating cost estimate and cost/benefit analysis of the conceptual pilot geothermal heating system is contained in the following Table A. The estimates are based on 1987 dollars, Canadian.

TABLE A
ESTIMATED CAPITAL AND OPERATING COSTS AND COST/BENEFITS

CAPITAL COSTS

1.	Supply well preparation for initial testing, including drill-out and perforating the existing 4-21 abandoned well, allows 6 days service rig time.	\$ 115,000
.2	3rd party costs to conduct initial well tests, allows 15 day test period with 5 days service rig time.	\$ 15,000
3.	Engineering Fees and Expenses to obtain regulatory approval and permits and to arrange for, inspect and report on the initial well testing.	\$ 45,000
4.	SUBTOTAL - WELL PREPARATION AND INITIAL TESTING	\$ 175,000
5.	Disposal well preparation for final testing, including drill-out and perforating the existing 6-14 abandoned well, allows 6 days service rig time.	\$ 105,000
6.	3rd party costs to conduct final well tests, allows 30 day test period with 10 days service rig time.	\$ 22,000
7.	Engineering Fees and Expenses to obtain regulatory approval and permits and to arrange for, inspect and report on the final well testing.	\$ 45,000
8.	SUBTOTAL - WELL PREPARATION AND FINAL TESTING	\$ 172,000

TABLE A (Continued)

9.	Supply well pump and controls 11.2 KW (15 HP) submersible vertical turbine constant speed well pump.	\$ 130,000
10.	Supply well discharge piping.	\$ 10,000
11.	Disposal well head piping.	\$ 5,000
12.	Well-to-well piping 5600 m plus 800 m return circulation loop to water reservoirs 100 mm dia. buried A/C	\$ 576,000
13.	Plate heat exchangers installed in water heating building at reservoir site.	\$ 20,000
14.	Engineering (15% of Items 9 to 13)	\$ 111,000
15.	Contingencies (10% of Items 9 to 13)	\$ 74,000
16.	SUBTOTAL - PILOT HEATING SYSTEM	\$ 926,000
17.	TOTAL CAPITAL COST	\$1,273,000

ANNUAL OPERATING AND MAINTENANCE (O & M) AND CAPITAL COSTS

18.	Well pump power cost to run 11.2 KW (10 KW input) pump for 6 months/year at \$0.54/KWH	\$ 2,400
19.	Other operation and maintenance cost allowed for at 2% of capital and contingency cost per annum except for well pump.	\$ 13,700
20.	Other operation and maintenance cost for well pump allowed at 22% of capital cost per annum for pump replacement every four years.	\$ 26,000
21.	SUBTOTAL - O&M COSTS	\$ 44,700
22.	Capital amortization (annual) Cost (8% - 20 years)	\$ 129,700
23.	TOTAL ANNUAL O&M AND CAPITAL COST	\$ 174,400

TABLE A (Continued)

COST/BENEFITS

24.	Total Life cycle present value cost (Capital + O&M at 8% for 20 years)	\$1,712,000
25.	Annual geothermal energy consumption (for water heating)	420,000 KWH
26.	Annual value of geothermal energy consumption (for water heating) based on natural gas energy cost of \$0.010/KWH with 70% assumed heating efficiency i.e. Item 21 x \$0.010 divided by 0.70	\$ 6,000
27.	Unit Geothermal Energy Cost i.e. Item 23 divided by Item 25	\$ 0.42/KWH
28.	1987 Edson Unit Electrical Energy Cost (used in Item 18 above) for comparison	\$ 0.054/KWH
29.	1987 Edson Unit Natural Gas Energy Cost (used in Item 26 above) for comparison	\$ 0.010/KWH
30.	Annual Utilization Factor, i.e. ratio of actual geothermal energy consumed to maximum energy available if the system is run at full capacity for the full year referenced to an injection (sink) temperature of 20°C, i.e. Item 25 divided by energy of 14.35 m ³ /hr. geothermal system flow capacity cooling from 45°C to 20°C for one year.	0.115

11.0 DISCUSSION

Estimated reduction in total well preparation and testing costs if the initial and final well tests were to be combined as a single 30 day supply and injection well test would be approximately \$33,000.

The analysis shows that the value of natural gas displaced by geothermal heat does not nearly offset the annual total cost of the geothermal heating system, as expected. If the system were fully utilized (i.e. a utilization factor of 1.0) the annual value of natural gas displaced would be \$52,200, which would offset the annual operations and maintenance cost of \$44,700, but would not nearly offset the total annual operations, maintenance and capital cost of \$174,400 per year.

A significant capital cost item in this analysis is the estimated \$504,000 cost of the 5,600 m well-to-well piping associated with the only two potential abandoned wells presently available for this project, or the approximate equivalent cost of drilling a new well for this purpose.

A more cost effectively located pair of existing wells within a common one of the identified potential Belly River reservoirs may become available sometime in the future. The timing of this of course is not possible to predict, however it may result in a capital cost reduction in the order of \$450,000.

12.0

CONCLUSIONS

Except for prolonged flow test measurement information of actual in place permeabilities of the prospective geothermal reservoirs, a significant amount of hydrogeological information is available as a result of active oil and gas well drilling activity in the area, and can be used, as was done in this study, to define with reasonable accuracy, the limits of geothermal reservoirs or pools within the available well depths, and to predict their geothermal potential. At the same time, having defined the locations

and depths of these reservoirs and their geothermal potential, the feasibility of using any of the existing wells for geothermal supply or disposal can be determined, and certain ones eliminated from further consideration.

Considering available heating loads and their location with respect to existing potentially usable and compatible well doublets for geothermal production, the number of alternatives available making use of these wells without excessive interconnection pipeline costs, becomes very limited.

Additional existing wells may become available in future, so that a more cost effectively located and suitable pair of existing abandoned wells may be used in the future to result in a substantially lower cost geothermal pilot heating system. Also suitable additional or increased heating loads may become available in future, resulting in a less costly system to operate.

Information presented in this study may be useful in future to assess the viability of existing wells and heating loads as they become available, for possible use in a geothermal system.

This study was based on test data available from petroleum exploration wells. Because testing for this purpose does not provide all the information necessary for geothermal development, significant assumptions had to be made that have a profound influence on the economic analysis. A well testing program as described herein is required as the next step to prove up certain of these assumptions such as long term capability, characteristics and suitability of the prospective supply well, disposal well and aquifer formation as a geothermal source for the pilot project.

The Town of Edson intends to continue considering additional heating loads such as recreational spa, greenhouse and other commercial uses, and other possible wells, that may become available in future for the geothermal pilot project.

13.0 RECOMMENDATIONS

It is recommended that either; a single (existing) supply well preparation and testing program as described herein at an estimated total cost of \$175,000, or a combined (existing) supply and disposal well preparation and testing program as described herein at an estimated total cost of \$314,00, proceed as the next step in the development of a geothermal pilot project to prove up long term capability, characteristics and suitability of the prospective supply well, disposal well and aquifer formation as a geothermal source for the pilot project.

It is also recommended that the status of oil and gas wells and potential low temperature heating loads in the immediate Edson area be monitored on a regular basis, with the objective of obtaining a more cost effectively located and suitable pair of existing abandoned wells and heating load(s) for use in a minimal cost geothermal heating pilot project, for purposes of advancement of geothermal energy technology, economics and development in Canada.

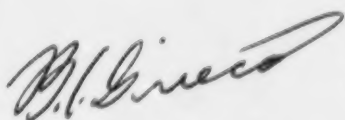
It is also recommended that the Town of Edson be advised in advance of all abandonment plans for existing wells in the immediate Edson area in future, so that they may take steps to avoid well abandonment procedures that may reduce the adaptability of such wells for conversion to geothermal use.

14.0. REFERENCES

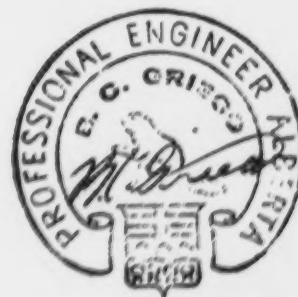
1. Acres Consulting Services Limited, Low Temperature Geothermal Energy Applications, National Research Council Contract: 05SX.31155-2-2801, March, 1983.
2. Nutchence, K., Vigrass, L.W., Law, A.G., Weston, J.H., Modelling of the Regina Geothermal Aquifer, published in Energy Developments: New Forms, Renewables, Conservation, Proceedings of Energex 1984, The Global Energy Forum, Regina Saskatchewan, Canada, May 14-19, 1984.
3. UMA Engineering Ltd., Feasibility Study in the use of Geothermal Energy to Heat Large Facilities in Edson, Alberta, Energy Mines and Resources Canada, Supply Services Canada Contract No. 1SQ 84-00138, July, 1985.

Respectfully submitted,

UMA Engineering Ltd.



B. C. Grieco, P.Eng.
Project Manager



PERMIT TO PRACTICE UMA ENGINEERING LTD.	
Signature	<i>K. Kuchinski</i>
Date	87-07-13
PERMIT NUMBER: P 329	
The Association of Professional Engineers, Geologists and Geophysicists of Alberta	

APPENDIX I
LICENSE APPLICATION FORMS AND INFORMATION

INTER OFFICE MEMO

Underwood McLellan Ltd.

TO file
FROM D. Phelps
RE EDSON GEOTHERMAL

DATE 1985 03 15

OUR FILE NO.
4193-006-00-1.2

Record of telephone conversation with ERCB concerning pumping and re-injecting geothermal water.

Don Graham, Edmonton (427-0200)

-licence application - requires legal survey location data on location to drainage patterns and bodies of water; data on location relative to surface improvements (water wells, roads, buildings, etc.); data on well construction, target formation, etc.

-ERCB studies application and makes a ruling; a licence for petroleum wells is usually granted in a few days unless there is an objection, then hearings are required and several months are often required to reach a decision

-re-injection is the main issue; if there is any chance of affecting oil and gas production then there could be objection

-there are no royalties on removal of water

-an existing casing can be re-entered; perforated and testing; a licence will be required.

Fred Sorensen, Development Department, Calgary (279-8159)

-both supply and re-injection wells require licencing

-withdrawal and re-injection from the same formation is unlikely to have any influence on oil or gas production

-re-injection at a shallower aquifer will require hydrogeologic and reservoir studies to determine the impact; because of the size of the Belly River Formation this aquifer may be suitable

-if wells are properly cased to avoid movement of water between formations, it is unlikely the owner of mineral rights will object to exploration and testing below the gas and oil producing formations

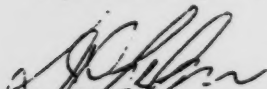
1985 03 15

INTER OFFICE MEMO Cont'd

... /2

- the owner of the mineral rights has no right to prevent drilling for the purpose of extracting water; the licence to remove or reinject water gives right of access through overlying formations
- a surface lease is required to gain access to land
- there are no royalties levied against removal of water
- injection of waste water is common in Edmonton; the Nisku Formation at about 7000 feet depth has been accepting waste water for many years from many industries with no apparent affect on the aquifer; individual wells take approximately 1,000,000 barrels per year.
- problems in re-injecting in higher aquifers are:
 - compatibility of waters - low formation water is considerably more saline
 - the disposal well may tend to plug up because of incompatible water chemistry
 - the upper aquifer may not accept surcharging and could affect other aquifers
- the next step would be to advance a preliminary disclosure to ERCB and discuss permits and approvals; Mr. Guy

Berndtsson, Assistant Manager, Drilling and Production, Development Department (297-8172) should be contacted.


D. Phelps

DP/cap



ENVIRONMENT

APPLICATION
for EXPLORATION PERMITPursuant to Sec. 15
THE WATER RESOURCES ACTAPPLICANT'S NAME: _____
Please type or print full name clearlyADDRESS: _____
Street, P.O. Box or R.R. No.

Phone No. _____ City, Town or Village _____ Province _____ Postal Code _____

hereby applies for authority to make all necessary examinations and surveys in order to evaluate the feasibility of obtaining a groundwater supply at the following location:

					W
LSD	or	Quarter	Section	Township	Range
					Meridian

for _____ purposes.
(e.g. domestic, subdivision, municipal, irrigation, industrial, drainage, etc.)

Anticipated depth interval to be investigated _____ feet to _____ feet.

Estimated daily requirement _____ Canadian gallons per day.

If anticipated use is seasonal, indicate those months during which water will be pumped: _____

Name of Consultant or Agent conducting investigation on my behalf _____

Permit to be forwarded to _____ Phone No. _____Date _____ 19 _____
Signature(s) of applicant or signing authorityType or print name and title of signing authority

OTHER APPLICATION FORMS

Under The Water Resources Act available on request
WR 1 - Licence - Sec. 11(1)(a) (b) and (c)
WR 1A - Drainage - Sec. 11(1)(d)
WR 1B - Permits - Sec. 11(1)(e)

FORWARD COMPLETED APPLICATIONS TO:

Controller of Water Resources
Alberta Environment
Oxbridge Place
9820 - 106 Street
Edmonton, Alberta. T6K 2J6

FOR WATER RIGHTS OFFICE USE ONLY:

Advertise _____ Defer _____
Immediately _____ Advertising _____

File No. _____

Unique No. _____

Year	Month	Day	Number

Recorded by: _____

Comments: _____

SEE OVER FOR INFORMATION FOR APPLICANTS

WR 1C (Rev. 1982)

EXCERPT FROM THE WATER RESOURCES ACT

15(1) An applicant for a licence or permit referred to in section 11(1) shall file with the Minister an application in writing in the form and containing the particulars that the Minister may from time to time prescribe and shall set out the nature of the proposed diversion or works and the purpose thereof.

(2) The Minister may in his discretion grant to the applicant an exploration permit on any conditions he thinks fit authorizing the applicant to make all necessary examinations and surveys to prepare plans and sections, showing the extent of the proposed operations and the land that will be affected by reason of any proposed diversion.

(3) The term of an exploration permit shall be one year from its date but the Minister may from time to time extend the term for a period not exceeding one further year.

(4) The person to whom an exploration permit is granted is entitled with any assistants that are necessary to enter into and on any public or private land to take levels, make surveys and do other necessary work for the purpose of completing the examination and survey authorized by the permit.

(5) No unnecessary damage shall be done on or to public or private land in entering thereon or in taking levels, in making surveys or in doing other necessary work for the purpose of completing the examination and survey authorized by the permit.

(6) The applicant, after completing the preliminary examination and survey, may file with the Minister an application for a licence, in the form and containing the particulars that the Minister may require, setting out the nature and extent of the proposed diversion or works.

(9) Notwithstanding anything in this Act, no person is entitled to apply for a licence under section 11(1) to divert and use ground water unless he has

(a) obtained an exploration permit under this section pertaining to an examination and survey of the source of the ground water, and

(b) has complied with the exploration permit, this section and the regulations,

and subsections (1) to (6) apply to the application and the exploration permit.

16(1) Subject to subsection (2), the Minister shall, forthwith after the filing of the application and plans, forward a notice of the filing to the office of the secretary-treasurer of the municipality in which the site of the proposed works is located, with a request that the notice be posted in a conspicuous and public place in his office for a period of 15 days from the date thereof, and the Minister shall also send 2 copies of the notice to the applicant who shall immediately post them and keep them posted for a period of 15 days from the date thereof at 2 conspicuous points at the site of the proposed works.

(2) Instead of proceeding under subsection (1), the Minister may require an applicant to publish in a newspaper published in the neighbourhood and to be named by the Minister, a notice of the filing of the application and plans.

(3) The notice referred to in subsection (2) shall be published at least once a week for 2 successive weeks, and shall contain a statement of the nature of the rights applied for and of the general character and location of the proposed works.

(4) Any person who objects to the granting of the application may, within a period of 30 days from the date of the first publication of the notice in the newspaper or the date of the posting of the notices in accordance with subsection (1), file with the Minister a statement of his reasons for objecting.



ENVIRONMENT
Environmental Protection Services
Standards and Approvals Division

9820 - 106 Street, Edmonton, Alberta, Canada T5K 2J6 Air Quality Branch 403/427-5872 Water Quality Branch 403/427-5888
Telex 037-2006, TWX 610-831-2636

The Clean Water Act

Application for A Permit or Licence

To: ALL APPLICANTS

1. Section One is to be completed by all applicants.
2. Section Two is to be completed by applicants for:
 - (a) a permit to construct a water facility;
 - (b) a permit to alter, add to, or change an existing water facility;
 - (c) a licence to operate a water facility.

NOTE: Where the applicant wishes to alter, add to, or change an existing water facility, the applicant must provide information which relates to the new operating level.

3. This application is to be completed to a level of completeness as determined by the Water Quality Branch of the Standards and Approvals Division.
4. Section Four is to be signed in the appropriate space.
5. Where sufficient space has not been provided in the above mentioned Sections, additional data sheets may be attached by the applicant.
6. Sections not applicable can be marked N/A.
7. The completed application and attachments are to be sent to:

Director of Standards and Approvals
Standards & Approvals Division
Alberta Environment
5th Floor, Oxbridge Place
9820 - 106 Street
EDMONTON, Alberta
T5K 2J6

Long Form
December, 1982

The Clean Water Act

Application for A Permit or Licence

Application No.: _____

Date Received: _____

Review by: _____

For Office Use Only

Section One: General Information

1.0 Date of Application: _____

1.1 Name of Applicant: _____

(Company or Corporation)

(Owner or Agent)

1.2 Name of Plant or Facility: _____

1.3 Address of Applicant: _____

(Street, Avenue, Road, R.R., Box, etc. City, Town, Village, Postal Code)

1.4 Telephone Number: _____

1.5 Location of Facility: _____

a) _____
(Street, Avenue, Road, R.R., Box, etc. City, Town, Village, Postal Code)

or b) LSD ___, 1/4, Section ___, Township ___, Range ___, ___ Meridian.

1.6 Application For:

(1) A Permit _____

(2) Permit Amendment _____

(3) A Licence _____

(4) Licence Amendment _____

1.7 Summary of Project: _____

1.8.0 Duration of the Project: _____

Construction Commencement Date: _____

Construction Completion Date: _____

1.8.1 Estimated Project Costs:

	Capital Cost Construction & Equipment (\$)	Annual Operating Cost (\$)
Water Pollution Abatement Equipment		
Air Pollution Abatement Equipment		
Other		
TOTAL		

1.9.0 Previous approvals issued for the applied project:

.1 Department of the Environment, Water Permit No. _____

.2 Department of the Environment, Water Licence No. _____

.3 Other Approvals _____

Section Two: Design and Emission Information

2.0.0 The applicant shall provide the following information as part of the submission. In the case of an amendment to a permit and/or a licence, the applicant should review the following section and present that material concerning the changes to the operation relative to the previous material already supplied.

2.1.0 Scale diagrams of the plant and the surrounding area are required. These diagrams shall include:

- .1 topography of the area;
- .2 property boundaries and land use of the area;
- .3 location and types of all buildings;
- .4 the exact location and name of all equipment used in manufacturing, processing or storage and other units;
- .5 location and name of all equipment used in control, treatment and disposal of waste water;
- .6 location of all sewer lines;
- .7 location of all discharge points; and
- .8 the location of the plant site.

NOTE: These diagrams may also include the surface drainage information specified in Section 2.8.1.

2.2.0 A flow diagram of the manufacturing process(es) or operation(s) involved, the waste water treatment facilities, and a general narrative description is required, including equipment and unit capacities.

2.3.0 List the unit products resulting from the processing operations, specifying the production unit.

Products	Units of Products	
	Per Typical Operating Day	Per Day At Maximum Capacity

2.4.0 List the raw materials required for the manufacturing process or operation.

Type of Raw Materials	Typical Quantity Per Day (tonnes/day)

2.5.0 List the chemicals required for production, the manufacturing process or operation.

Type of Chemicals	Typical Quantity Per Day (kg/day)

NOTE: A material balance flow sheet (block diagram) for the entire plant operations must be submitted.

2.6.0 Water Supply: List the source of water supply, its purpose and quantities.

Type of Operation	Source of Water	Total Consumption (m^3 /day)

2.7.0 Final Liquid Effluent Discharged: Identification of Water Contaminants.

Total volume per day _____ m³.

Water Contaminant	Concentration (mg/l)	Discharge Rate		Continuous Discharge or Intermittent	Frequency (If Intermittent)
		(kg/day)	kg/unit of production		

*eg. BOD₅, COD, Total Suspended Solids, Heavy Metals, Odours, Phenols, Sulphides, Oil and Grease, Phosphates, Ammonia-Nitrogen, etc.

2.7.1 Liquid Effluent: Identification of Individual Sources

Source of Liquid Effluent	Volume (m ³ /day)	Temperature (°C)	pH	Principal Water Contaminants	Frequency of Discharge

2.7.2 Cooling Water: Once Through _____
Circulating _____

Flow Rate (m ³ /day)	Water Temperature (°C)		If Circulating System Blowdown Rate (m ³ /day)	Rate Dissipation In Receiving Water (kilojoules/hr)
	Intake	Discharge		

Conditioner Added to Cooling Water*	Name of Compound	Final Concentration* (mg/l)	Frequency of Application

* Biocides, Fungicides, Corrosion Inhibitors, etc.

Note: A water balance flow sheet (block diagram) for the entire plant must be submitted.

2.7.3 Raw Water Treatment

- (a) Filter Backwash _____
- (b) Boiler Blowdown _____
- (c) Ion Exchange Resin Regeneration _____
- (d) Removal of Sludge, Deposition, Corrosive Materials _____
- (e) Other _____, please give details _____

- (f) Method of Disposal of Treatment Wastes _____

2.7.4 Sanitary Sewage Effluent:

- (a) Number of Personnel _____
- (b) Volume of Water Discharged _____ (m^3/d)
- (c) Method of Disposal of the Sanitary Sludge _____

Note: (i) When disposal is to a municipal sewage system, a letter of confirmation from the municipality must be submitted.
(ii) When disposal is to a septic tank and field, leaching cesspool or any other approved in-ground disposal system, confirmation from the Plumbing Inspections Branch of Alberta Labour approving the design of the system must be supplied.

2.8.0 Surface Drainage:

.1 Topographic map(s) shall be submitted, showing the following:

- (a) Plant site and any associated mine site layout with major facilities
- (b) Off-site areas contributing storm water runoff to the site surface drainage system
- (c) Facilities provided for the collection, segregation, protection, treatment and discharge of storm water runoff from the various areas of the site and off-site.

Note: The topographic map(s) should reflect any proposed contour changes to the natural topography.

- .2 The following storm runoff information shall be submitted for the site(s):

- (a) Area contributing surface runoff - Ha
- (b) Runoff Volume from a 10-year storm of 24-hour duration - m^3 (based on the applicable rainfall data for the area);
- (c) Peak Runoff Flow from a 10-year storm at point of discharge to a treatment facility - m^3/s .

Note: The Rational Formula can be used to obtain estimates of the above figures.

Rational Formula:

$$Q = CIA$$

where

Q = runoff flow (m^3/s)

C = runoff coefficient (see page 12 for a rough guide)

I = rainfall intensity (m/s)

A = contributing area (m^2)

- .3 The following information on the storm water facilities shall be submitted:

- (a) Design of storm water treatment or retention facilities (attach drawings);
- (b) Methods and parameters used in the calculation of the design storm runoff;
- (c) Description of the methods for minimizing storm water contamination.

Note: Where available, provincial guidelines for the relevant industry category should be consulted to ascertain specific requirements.

- .4 (a) Is there any possibility of spilling any raw materials and/or any final products which may cause pollution?

Yes _____ No _____

If yes, what are the raw materials and/or final products?

(b) Frequency of spilling _____

(c) Is there any pollution control if the above-stated spill may occur?

Yes _____ No _____

RATIONAL METHOD

C

Table VIII.1 Runoff Coefficients for Urban Areas

Description of Area	Runoff Coefficient
Flat, residential, with about 30% of of area impervious	0.40
Moderately steep, residential, with about 50% of area impervious	0.65
Moderately steep, built up, with about 70% of area impervious	0.80

(Horner and Flynt 1936)

Table VIII.2 Deductions from Unity to Obtain the Runoff Coefficient
for Agricultural Areas

$$C = 1 - (a + b + d)$$

Type of Area	Values of C
Topography	
Flat land, with average slopes of 1 ft. to 3 ft. per mi.	0.30
Rolling land, with average slopes of 15 ft. to 20 ft. per mi.	0.20 -a
Hilly land, with average slopes of 150 ft. to 250 ft. per mi.	0.10
Soil	
Tight impervious clay	0.10
Medium combinations of clay and loam	0.20
Open sandy loam	0.40
Cover	
Cultivated lands	0.10
Woodland	0.20 -d

(Bernard 1935)

* In Table VIII.2, the magnitude of C is obtained by adding values of C for each of the three factors: topography, soil and cover, and then by subtracting the sum from unity.

Gray, Donald M., Handbook on the Principles of Hydrology. Water Information Centre, Inc. 1970. Page 8.5

2.9.0 Liquid Effluent Treatment Facilities:

- .1 Pretreatment, e.g., screening, grit removal, comminution units, etc.

Yes _____ No _____

If yes, give a full description of the design, handling volume and efficiency (attach drawings):

- .2 Primary Treatment, e.g., sedimentation tank, clarifier, separator, etc.

Yes _____ No _____

If yes, give a full description of the design, handling volume, retention time, efficiency, etc. (attach drawings):

- .3 Secondary Treatment, e.g., activatee sludge, trickling filters, oxidation ponds (biological lagoon), chemical treatment, etc.

Yes _____ No _____

If yes, give a full description of the design, handling volume, retention time, efficiency especially the percent of BOD₅ and total suspended solids reduction (attach drawings):

- .4 Tertiary Treatment, e.g., supplemental sedimentation, nutrient removal, tertiary filtration, ion exchange, etc.

Yes _____ No _____

If yes, give a full description of the design, handling volume, retention time, and efficiency (attach drawings): _____

_____.

- .5 Other Treatments:

Chlorination _____

Activated Carbon _____

Others _____

- .6 How are the solid wastes being disposed, e.g., sludge, garbage, etc? Provide details requested in the Appendix I.

- .7 Structure of the liquid effluent or cooling water outfall. Give a brief description of the design. _____

Section Three: Statements

3.0 The applicant shall discuss the following points:

- .1 Describe the different processes or operations that may cause different rates of contamination. Describe and show how they will be different;
- .2 Describe the potential for accidents and emergencies and the contingency procedures to minimize the potential damage;
- .3 Proposed method and frequency for monitoring waste water, volume flow rates, and concentrations of water contaminants;
- .4 A brief statement assessing the impact of the operation or manufacturing process on the surrounding environment.

Section Four

- 4.0 This application is submitted in accordance with the Clean Water Act, and may require the applicant to submit any additional information considered necessary regarding the proposed water facility.

An application for a Permit or Licence shall not be deemed to be filed until all the information, documents, and authorizations in the application form have been received.

(Date)

(Signature)

(Title of Signature)

NOTE: The application must be signed
by the owner or his agent.

APPENDIX I

APPLICATION FORM FOR APPROVAL OF AN INDUSTRIAL LANDFILL

Application No.: _____

Date Received: _____

1. General Information

1.1 Date of Application: _____

1.2 Name, address and phone number of applicant: _____

1.3 Name, address and phone number of owner/operator: _____

1.4 Legal land description of disposal site: _____

1.5 Summary of project: _____

2. Design Considerations

2.1 Production rate of each waste and concentration of components;

2.2 Physical and chemical properties (hazards, if any, associated with the wastes);

2.3 Detailed design and description of disposal methods;

2.4 Physical and chemical properties of the materials to be used as liners, buffers, and intermediate and final covers;

2.5 Potential of materials described in 2.4 to retard movement and/or provide neutralization of hazardous components of the wastes.

3. Hydrogeological Characteristics

- 3.1 Water table level;
- 3.2 Groundwater flow directions and rates;
- 3.3 Background quality of groundwater within the expected zone of influence;
- 3.4 Distances of water sources (ground and surface water) from the disposal site;
- 3.5 Present and future groundwater uses which could be affected.

4. Geographical and Geological Characteristics

- 4.1 Topography of the area;
- 4.2 Landfill boundaries and land use of the area;
- 4.3 Surficial geology (classification, permeability, and moisture content of the soil);
- 4.4 Bedrock geology.

5. Details of the Monitoring System

6. Reclamation of the Site

- 6.1 Closure and post-closure procedures;
- 6.2 Future use of the site.

7. Local Authority Approval

- 7.1 Provide copy of development permit.

APPENDIX II
SPROULE ASSOCIATES LTD.
GEOLOGICAL REPORT

THIS REPORT HAS BEEN PREPARED
FOR THE EXCLUSIVE USE OF:

UMA ENGINEERING
LTD./5849

COPY NO: 5

**GEOHERMAL DEMONSTRATION/
PILOT PROJECT,
EDSON, ALBERTA**

Prepared for
UMA Engineering Ltd.
April, 1987

SPROULE ASSOCIATES LIMITED

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A GEOLOGICAL AND ENGINEERING STUDY
OF THE GEOTHERMAL POTENTIAL
OF THE BELLY RIVER GROUP

INTRODUCTION

This section of the report summarizes the geothermal energy potential of the Upper Cretaceous Belly River Group in the Edson area of Alberta. Five water-bearing reservoirs have been identified and mapped, and their geothermal potential evaluated. These reservoirs are represented by a series of eight maps and two stratigraphic cross sections accompanying the text. An updated inventory of wells drilled within two kilometres of the town of Edson has been assembled. From this data, a short list of wells which may be used for this project has been established. A list of formation temperatures and an estimate of original water-in-place for each pool has been determined. A series of recommendations follow the text.

RESERVOIR ANALYSIS, BELLY RIVER GROUP

GENERAL STATEMENT

A detailed assessment of the reservoirs within the Upper Cretaceous Belly River Group, over a six mile by six mile block centered on the town of Edson, Alberta (Figure 1), was conducted. Well logs, drill stem tests, production data and other pertinent information from 50 wells within and adjacent to the study area were analyzed to determine the number of water-bearing Belly River pools within a two kilometre radius of the town of Edson. Only those pools which display good lateral consistency and reach to within two kilometres of the townsite were considered in this study.

Five potential geothermal source zones have been delineated in this study (Figures 2 to 10). These occur within two kilometres of the town of Edson, Alberta, and have been assigned the following informal names, in descending order.

Belly River 'A' Sandstone

Belly River 'B' Sandstone

Belly River 'C' Sandstone

Belly River 'D' Sandstone

Belly River 'E' Sandstone

Each of these geothermal resource pools is represented by an isopach map depicting the net pay for the effective water-bearing zones (Figures 2 to 6 inclusive). A structure map, representing the top of the effective porosity, Belly River 'A' sandstone (Figure 7), and a pool outline map (Figure 8) depicting the lateral extent of all five pools are also included. Two stratigraphic cross sections, A-A', B-B', extending across the area (Figures 1, 8, 9 and 10) depict the vertical relationships between the five geothermal resource pools.

Across the study area, the pools tend to dip in a southwesterly direction. The structure map drawn on the top of the effective porosity within the Belly River 'A' sandstone (Figure 7) indicates a maximum variation in elevation approaching 50 metres

from the northeast to the southwest. The structural orientation of the other pools, as seen in cross sections A-A' and B-B' (Figures 9 and 10), is similar.

The pools are distributed throughout the Belly River Group. The 'A' sand is found just below the top of the Belly River (Figures 9 and 10). The Belly River 'E' Pool lies about 70 metres above the top of the Lea Park shale sequence, which has a maximum subsea depth locally of -625 metres. Geothermal wells would need to be completed no deeper than 1,600 metres from surface to develop any of these pools.

The five Belly River geothermal pools, as presented in Figures 2 to 6 inclusive, have a number of similar characteristics.

- (a) Each pool is of restricted aerial extent and thickness.
- (b) Each pool is bounded laterally and vertically by relatively impermeable lithologies, such as tight siltstones and shales.
- (c) None of the pools, as mapped, form a part of a large regional aquifer.
- (d) Because the pools are of limited, finite extent and there is no natural driving mechanism to aid in water production, both rates and volumes of water would drop rapidly upon commencement of production.

Should production be attempted from any of these pools, it would be very short-lived, because no apparent re-charge system has been mapped. The only way to achieve sustained production from any or all of these pools is to establish a cyclic system, involving injection of water into the pool from which it is being produced.

Regionally, the Basal Belly River sandstones form a good reservoir, laterally extensive and thick. Locally, the Basal Belly River exhibits poor reservoir quality; low porosity, low permeability, and argillaceous sediments. Thus, within the study area, the Basal Belly River is not considered as a suitable geothermal source.

Paleo Environment

Log analysis of the Belly River Group from 50 wells in and adjacent to the study area shows that it is a sequence of terrigenous clastics and coals deposited in a continental-fluvial to low-lying flood plain environment. The sand bodies, among which are the five potential geothermal resource pools, are fluvial in origin, probably point bar deposits. As such, they form discrete entities, probably isolated both vertically and laterally from similar lenticular sand bodies beyond the limits of the study area. The nature of these sediments precludes the development of a large scale regional aquifer.

Lithology

Log analyses of the Belly River Group from 50 wells in and adjacent to the study area indicate that the five reservoirs here considered consist predominantly of fine-grained argillaceous sandstones, grading both vertically and laterally to relatively impermeable siltstones and shales. Locally, cleaner portions of the sandstones containing less argillaceous material are well cemented, reducing both effective porosity and permeability.

Reservoir Quality

The quality of the five Belly River reservoirs evaluated in this study is of somewhat questionable value. Historically, no oil or gas production has been associated with these Belly River sandstones locally, and as a result records of most companies as they drill through this interval are not extensive. The suite of well logs run over the zone is very limited due to lack of hydrocarbon potential, and sampling of drill cuttings through this zone is not done with great care. No cores have been cut through any of these reservoirs within or adjacent to the study area. Thus, detailed core analyses are not available to substantiate well log interpretations.

During log analysis, it became apparent that there was good porosity correlation between the Sonic log and the Density Porosity log. These were used for porosity determinations, supplemented where available by data from the Spontaneous Potential,

Caliper and Microlog data. Minimal effective porosity considered in this study is 10 percent, based on the Density or Sonic logs. This value is low for an argillaceous sandstone and therefore may give a somewhat optimistic picture of reservoir size. However, supporting logs, such as the Spontaneous Potential, the Caliper and the Microlog logs, suggest effective porosity in these intervals and thus they are included.

Drill stem test data for the Belly River locally is very sparse. Two reservoirs within two kilometres of the town of Edson have been tested. The Belly River 'A' Pool was tested in Lsd. 16-17-53-17 W5M. The interval tested was from 1,260 to 1,277 metres. During the test, they received gas to surface too small to measure and recovered 960 metres of gas-cut fresh water and 60 metres of gassy, water-cut mud. The Belly River 'C' Pool was tested in Lsd. 9-29-53-17 W5M. The interval tested was 1,376 to 1,381 metres. During the test, there was no evidence of natural gas, and they recovered 971 metres of muddy fresh water. To date, the other reservoirs have not been tested, however, log analyses suggest they are of similar quality to those mentioned.

Figure 8, presenting an outline of the five geothermal resource pools, is a most useful map in that it displays the vertical stacking of the pools. It thus establishes target areas where three to four of the pools overlap, offering potential for several zones to be developed with a minimal amount of drilling. Sections 15, 16, 21 and 22, Township 53, Range 17, West of the Fifth Meridian offer the greatest potential for success.

Reservoir Temperatures

Based on the temperature log acquired from the recently drilled and currently confidential well in Lsd. 10-20-53-17 W5M, the following reservoir temperatures have been calculated:

Belly River 'A' Sandstone	46°C
Belly River 'B' Sandstone	47°C
Belly River 'C' Sandstone	47°C
Belly River 'D' Sandstone	48°C
Belly River 'E' Sandstone	49°C

It should be realized that these temperatures are based on data from one well. The temperature log was run approximately eight hours after circulation had ceased in the wellbore, allowing the fluids to approach a temperature equilibrium. Thus, the log data should be relatively reliable. It should be noted that the reservoir temperature will vary slightly across each pool due to slight changes in depth, but this variation, when compared to other uncertainties, such as permeability, is insignificant.

Reservoir Porosity

From calculations based on well log interpretations, average porosity values have been determined for each pool (^{Table} Figure-2). Values range from 16 percent for the Belly River 'A' Pool to 12 percent for the Belly River 'E' Pool. No core-derived porosities were available for this study.

Reservoir Volume

From calculations based on well log interpretations, average porosity and water saturation values have been derived for each pool. Water saturations varying from 95 percent in the Belly River 'A' and 'B' Pools to 100 percent in the Belly River 'E' Pool have been determined from log analysis and are presented in Table 2. The remaining reservoir volumes within the Belly River reservoirs (0 to 5 percent) are gas saturated. This gas saturation is not unexpected in the region and has been substantiated by the production test carried out on the well located in Lsd. 16-17-53-17 W5M in which a gas blow too small to measure was recorded during the test. The reservoir parameters presented in Table 2, combined with the areal extent and thickness of each reservoir, have led to the

determination of original water-in-place (Tables 2 and 3). It is to be noted that the total water-in-place approaches $44 \times 10^6 \text{m}^3$. The Belly River 'A' Pool is the largest, containing close to $18.5 \times 10^6 \text{m}^3$ of water. This pool would probably form the best target area, as it is much larger than the other pools and has better porosity.

Reservoir Permeability

To date, with the exception of the two drill stem tests previously noted, and indirect evidence from the Spontaneous Potential, Microlog and Caliper logs, very little evidence exists to confirm the degree of permeability of the five Belly River reservoirs. From the available data, no accurate assessment can be made at this time. An actual measure of permeability is best established through a prolonged production test, recording pressure drawdown and buildup times. Due to lack of interest in these zones by those in search of hydrocarbons, no such work has been completed. Therefore, any permeability values expressed in this report should be considered as an order of magnitude rather than an accurate value.

Anticipated Reservoir Productivity

Due to the isolated nature of the five Belly River reservoirs, and the lack of a natural driving mechanism for each pool, it is anticipated that primary recovery of water-in-place would be minimal. As no production profiles are available for water in this area, no actual figures will be presented in this report. It is our opinion that the only way to avoid extremely rapid drawdown in such reservoirs is to set up a producer-injector couplet for each of the reservoirs to be exploited. The volumes withdrawn should be replaced through an injector, tapped into the same reservoir. The wells should be far enough apart to allow the injected water to reach formation temperature before it is produced again.

POTABLE WATER

Within the study area, no hydrocarbons are being produced from reservoirs above the Belly River Group, and very little interest has been expressed in this upper portion of the stratigraphic section.

The top of the Belly River Group is at least 1,000 metres below ground surface throughout the study area. Local supplies of potable ground water are obtained from the river flowing south of the town of Edson and from shallow aquifers in most cases 1,000 metres or more above any of the Belly River sandstone reservoirs considered in this study. Separating the system of potable ground waters from these reservoirs lies a sequence of shales and siltstones having very low effective porosity and permeability. These aquitards for all interests and purposes isolate the reservoirs from the overlying supplies of potable water.

HYDROCARBON PRODUCTION

Locally, oil and natural gas have not been produced from Belly River reservoirs, but small amounts of natural gas have been recovered with water on drill stem tests. A portion of this gas may be solution gas escaping from formation waters upon release of pressure. The remainder represents small non-commercial accumulations of natural gas trapped within the confines of the geothermal reservoir. No identifiable gas cap has been noted in any of the geothermal resource pools delineated in this study.

Locally, hydrocarbons are being produced from the Upper Cretaceous Cardium Formation, the Lower Cretaceous Gething Formation, and the Mississippian Elkton and Shunda formations. At least 450 metres of section, predominantly marine shales, lie between the lowest Belly River (E) pool considered in this study and the Cardium oil reservoirs. This relatively thick section of aquitards provides a substantial barrier isolating the five Belly River geothermal pools for local hydrocarbon reserves.

INVENTORY OF EXISTING OIL AND GAS WELLS

Table 1 presents a listing of oil, gas and abandoned or suspended wells which currently exist within the study area. The operator and current well status are included in the table.

OPTIONAL GEOTHERMAL SOURCES

A total of 48 wells have been drilled in the study area. Of these, six have been abandoned, and five have been suspended. Of these eleven wells, the following are within two kilometres of the town of Edson.

Lsd. 6-14-53-17 W5M ('A' and 'D' Pools)	Abandoned Well
Lsd. 4-21-53-17 W5M ('A' and 'B' Pools)	Abandoned Well
Lsd. 10-22-53-17 W5M ('D' and 'E' Pools)	Abandoned Well (1972)
Lsd. 10-22-53-17 W5M ('D' and 'E' Pools)	Suspended (1987)

These wells, combined with a new well strategically placed in Section 15, 16, 21 or 22, could provide access to as many as four of the five prospective geothermal resource pools.

Casing has been run in both the 6-14 and 4-21 wells to depths far below those considered in this study. In the 4-21 well, the casing above the Belly River reservoirs has been perforated and cement has been squeezed into the formation at 945 to 946 metres and 305 to 306 metres. The well was then capped with a cement plug from 229 to 320 metres. The casing (4-1/2 inch O.D.) could be cleared and re-entered but has been damaged by perforations, and it is not recommended that this be done. The possibility of contaminating the overlying formations through the perforations exists, and this event should be avoided.

Casing has been run in the Canadian Jorex 10-22 well to total depth and currently the well is considered by Jorex as suspended. Until they decide to abandon the well, it remains unavailable for this project. Potential exists to take over the hole before abandonment plugs are run, providing access to new undamaged casing. However, the well penetrates only the Belly River 'D' and 'E' Pools, which contain only 30 percent of the projected geothermal resources.

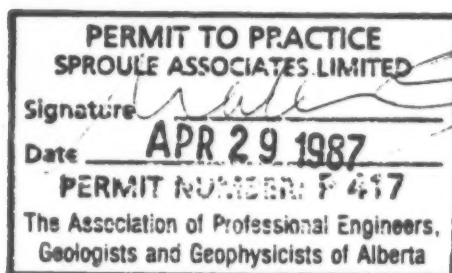
SUMMARY

The following is a summation of the findings arrived at during an evaluation of the geothermal energy potential of the Upper Cretaceous Belly River Group.

- (1) Five discrete water-bearing sandstone bodies have been identified within the Belly River Group. These have been given the informal names of 'A', 'B', 'C', 'D' and 'E' from the uppermost sandstone to the lowest.
- (2) These sandstone reservoirs appear to be isolated both vertically and laterally from each other and from other sandstones beyond the study area. They apparently do not form part of a large regional aquifer.
- (3) The permeability of these reservoirs is suggested from drill stem test data and well log information, but has not been accurately determined from either a core analysis or a prolonged flow test.
- (4) Three abandoned wells are located within the bounds of the study area. The current condition of the well casing is suspect. Therefore, it is our recommendation not to use these wells for this project.
- (5) One suspended well, Canadian Jorex 10-22-53-17 (W5M), is located in a good position for this study. The possibility exists to take over the hole before abandonment procedures are carried out. This well may be useable for the geothermal pilot project.
- (6) The map (Figure 8) portraying pool outlines suggests the best areas for the location of a geothermal well couplet (one producer and one injector) would be in Sections 15, 16, 21 and 22.
- (7) If the 10-22 well became available ('D' and 'E' pools), it is recommended that another well be drilled in Section 15 or 22 to assure accessibility to the 'D' and 'E' pools. These pools are not as large as the 'A' Pool, but the cost of access is considerably reduced if the 10-22 well is used.

- (8) Due to the finite, rather limited extent of the pools, as mapped, and the lack of a natural driving mechanism for water production, the project must be set up as a producer-injector couplet. Water must be injected into the same reservoir from which it is being withdrawn to maintain an adequate supply.
- (9) Reservoir data suggests that the 'A' Pool is the best reservoir for the project. Ideally, a new producer-injector system involving the drilling of two new wells, in Sections 15, 16, 21 and 22, incorporating an insulated pipeline and injection facility should be constructed. The costs of such a project may very well be prohibitive at this time.

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[Signature]
K. H. Crowther, P. Eng.

140 Fourth Avenue S.W.
Calgary, Alberta
April 30, 1987
MWS/paob
//MWS/5849-UMA

TABLE 1
LIST OF WELLS

Well I.D.	Well Name/ License No.	Field/ OS Area	Pool/ OS Deposit	Operator/ License	Well Status	T.D.	FD Date
00/11-02-053-17 W5/0	Champlin et al Edison 11-2-53-17 0026218	0320 Edson		0236 Champlin Can	Abandoned	2650.50	64-07-14
00/14-02-053-17 W5/0	APL et al Edison 14-2-53-17 0098908	0320 Edson	176062 Card RR & ZZ	380 APL O+G 0380 APL O+G	CR-011 Flow	2117.00	82-12-13
00/06-03-053-17 W5/0	Gulf Shell Edison 6-3-53-17 0093534	0320 Edson	176037 Cardium KK	0002 Gulf Can. Ltd. 0002 Gulf Can. Ltd.	CR-011 Flow	1940.00	82-01-14
00/06-07-053-17 W5/0	HB Gas Unit No. 1 Edison 6-7-53-17 0053593	0320 Edson	639060 ELA-SHA+SHB	038 Hudson's Bay 0038 Hudson's Bay	Flow	2737.10	75-07-04
00/11-08-053-17 W5/0	Royallite Edison 11-8-53-17 0026112	0320 Edson	639060 ELA-SHA+SHB	038 Hudson's Bay 08W1 Gulf Canada	Flow	2697.50	64-07-06
00/16-08-053-17 W5/0	Gulf Edison 16-8-53-17 0088173	0320 Edson	176021 Cardium U	0002 Gulf Can. Ltd. 0002 Gulf Can. Ltd.	CR-011 Pump	1938.00	81-02-18
00/15-09-053-17 W5/0	Gulf Edison 15-9-53-17 0077864	0320 Edson	176010 Cardium J	0002 Gulf Can. Ltd. 0002 Gulf Can. Ltd.	CR-011 Flow	1925.00	80-02-11
00/08-10-053-17 W5/0	APL et al Edison 8-10-53-17 0101953	0320 Edson	176062 Card RR & ZZ	380 APL O+G 0380 APL O+G	CR-011 Flow	2130.00	83-07-23
00/06-14-053-17 W5/0	Home Edison 6-14-53-17 0086026	0320 Edson		0FC4 J & H Constr.	Abandoned	2280.00	80-11-12
00/06-15-053-17 W5/0	APL et al Edison 6-15-53-17 0102603	0320 Edson	176062 Card RR & ZZ	380 APL O+G 0380 APL O+G	CR-011 Flow	2125.00	83-10-05
00/14-15-053-17 W5/0	Precamb et al Edison 14-15-53-17 0114389	0320 Edson	176062 Card RR & ZZ	08F3 Precambrian 08F3 Precambrian	CR-011 Flow	2030.00	85-06-18
00/16-17-053-17 W5/0	Gulf Edison 16-17-53-17 0071296	0320 Edson	176010 Cardium J	0002 Gulf Can. Ltd. 08W1 Gulf Canada	CR-011 Flow	2095.00	78-12-10
00/10-18-053-17 W5/0	Czar et al Edison 10-18-53-17 0084469	0320 Edson	326098 Geth Und	0P49 Czar Res.	Snag	2657.00	80-12-23
00/10-19-053-17 W5/0	HB Hamilton Edison 10-19-53-17 0023700	0320 Edson	639060 ELA-SHA+SHB	038 Hudson's Bay 0038 Hudson's Bay	Flow	2685.00	63-02-24

TABLE 1 - Continued

Well I.D.	Well Name/ License No.	Field/ OS Area	Pool/ OS Deposit	Operator/ License	Well Status	I.D.	FD Date
00/14-19-053-17 W5/0	Gulf Dome Edeon 14-19-53-17 0091072	0320 Edeon	176023 Cardium W	0002 Gulf Can. Ltd.	Sup	2155.40	81-07-27
00/06-20-053-17 W5/0	Gulf Kaiser Edeon 6-20-53-17 0080923	0320 Edeon	176010 Cardium J	0002 Gulf Can. Ltd.	CR-011 Flow	1940.00	80-02-27
00/10-20-053-17 W5/0	Atlas YK et al Edeon 10-20-53-17 0124375	0320 Edeon	Conf.	DC8 Atlas Yellowk DC8 Atlas Yellowk	CR-011 Pump	2235.00	86-12-07
00/04-21-053-17 W5/0	Chaplin et al Edeon 4-21-53-17 0025640	0320 Edeon	639060 ELA-SHA+SHB	038 Hudson's Bay 08N1 Gulf Canada	Abandoned	2761.50	64-03-02
00/06-21-053-17 W5/0	Atlas YK et al Edeon 6-21-53-17 0114230	0320 Edeon	176062 Card RR & ZZ	L30 Reaman DC8 Atlas Yellowk	CR-011 Flow	2110.00	85-06-12
00/14-21-053-17 W5/0	APL et al Edeon 14-21-53-17 0099816	0320 Edeon	176062 Card RR & ZZ	380 APL O+G 0380 APL O+G	CR-011 Flow	2125.00	93-01-30
00/10-22-053-17 W5/0	Atkinson et al Edeon 10-22-53-17 0041787	0320 Edeon		0380 APL O+G	Abandoned	3654.60	72-02-29
00/10-22-053-17 W5/0	CJK et al Edeon 10-22-53-17	0320 Edeon		Canadian Jorex	Suspended	2254.00?	?
00/10-26-053-17 W5/0	Chaplin et al Edeon 10-26-53-17 0026615	0320 Edeon	176002 Cardium B	FK2 Bridges Energy 0FK2 Bridges Energy	CR-011 Pump	1883.40	64-08-17
00/04-28-053-17 W5/0	CAI Res et al Edeon 4-28-53-17 0106359	0320 Edeon	176062 Card RR & ZZ	L30 Reaman 0L30 Reaman	CR-011 Flow	1952.00	84-03-25
00/04-29-053-17 W5/0	Res et al Edeon 4-29-53-17 0099450	0320 Edeon	176062 Card RR & ZZ	L30 Reaman 0L30 Reaman	CR-011 Flow	1940.00	83-01-10
00/08-29-053-17 W5/0	Res et al Edeon 8-29-53-17 0098101	0320 Edeon	176062 Card RR & ZZ	L30 Reaman 0L30 Reaman	CR-011 Flow	1945.00	82-11-26
00/09-29-053-17 W5/0	HB Convnt Edeon 9-29-53-17 0088992	0320 Edeon	176062 Card RR & ZZ	038 Hudson's Bay 0038 Hudson's Bay	CR-011 Flow	1940.00	81-03-13
00/06-30-053-17 W5/0	HB Edeon 6-30-53-17 0031946	0320 Edeon	639060 ELA-SHA+SHB	038 Hudson's Bay 0038 Hudson's Bay	Flow	2674.60	67-04-10
00/16-30-053-17 W5/0	Gulf Edeon 16-30-53-17 0092176	0320 Edeon	176035 Cardium II	002 Gulf Can. Ltd. 0002 Gulf Can. Ltd.	CR-011 Flow	1945.00	81-10-13
00/06-31-053-17 W5/0	HB Edeon 6-31-53-17 0025207	0320 Edeon	639060 ELA-SHA+SHB	038 Hudson's Bay 0038 Hudson's Bay	CR-011 Flow	2693.50	63-12-31

TABLE 1 - Continued

Well I.D.	Well Name/ License No.	Field/ OS Area	Pool/ OS Deposit	Operator/ License	Well Status	I.D.	FD Date
00/06-31-053-17 W5/0	HB Edeon 6-31BY-53-17 0041498	0320 Edeon	326001 Gething A	038 Hudson's Bay 0038 Hudson's Bay	Flow	2519.20	72-01-05
00/16-31-053-17 W5/0	APL et al Edeon 16-31-53-17 0098787	0320 Edeon	176062 Card RR & ZZ	380 APL O+G 0380 APL O+G	CR-011 Flow	2127.00	82-12-06
00/06-32-053-17 W5/0	C&T et al Edeon 6-32-53-17 0105386	0320 Edeon	176098 Card SD Und	L30 Resman 0130 Resman	CR-011 Flow	1932.00	84-02-04
00/10-32-053-17 W5/0	HB Edeon 10-32BY-53-17 0042400	0320 Edeon	326001 Gething A	038 Hudson's Bay 0038 Hudson's Bay	Flow	2503.90	72-06-17
00/12-32-053-17 W5/0	C&T et al Edeon 12-32-53-17 0104936	0320 Edeon	176062 Card RR & ZZ	L30 Resman 0130 Resman	CR-011 Pump	1935.00	84-01-17 ZZ
00/12-32-053-17 W5/2	C&T et al Edeon 12-32-53-17 0104936	0320 Edeon	176050 Cardium XX	L30 Resman 0130 Resman	CR-011 Flow	1935.00	84-01-17 ZZ
00/02-35-053-17 W5/0	Champlin et al Edeon 2-35-53-17 0027447	0320 Edeon	176002 Cardium B	FK2 Bridges Energy 0FK2 Bridges Energy	CR-011 Pump	1871.50	65-02-05 1
00/12-35-053-17 W5/0	Champlin et al Edeon 12-35-53-17 0027895	0320 Edeon	176002 Cardium B	FK2 Bridges Energy 0FK2 Bridges Energy	CR-011 Pump	1865.40	65-03-15 14
00/06-01-053-18 W5/0	Pen An F-1 Edeon 6-1-53-18 0030905	0320 Edeon	639060 ELA-SHA-SHB	038 Hudson's Bay 0060 Amoco Can. Pet.	Flow	2777.60	66-10-15
02/06-01-053-18 W5/0	Amoco Edeon 6-1-53-18 0061508	0320 Edeon	176003 Cardium C	DC8 Atlas Yellowk 00C8 Atlas Yellowk	CR-011 Flow	2042.20	76-12-20
00/04-12-053-18 W5/0	Shelter Edeon 4-12-53-18 0083547	0320 Edeon	176003 Cardium C	L27 Co-Enerco 0807 Assmura Inc.	CR-011 Flow	2008.00	80-12-19
00/04-13-053-18 W5/0	HB et al Edeon In 4-13-53-18 0036172	0320 Edeon	126098 BR Und	038 Hudson's Bay 0038 Hudson's Bay	Abandoned	1618.50	69-05-22
00/06-13-053-18 W5/0	HB Gas Unit 1 Edeon 6-13-53-18 0055625	0320 Edeon	639060 ELA-SHA-SHB	038 Hudson's Bay 0038 Hudson's Bay	Capped	2776.70	75-12-18
00/06-24-053-18 W5/0	HB Gas Unit 1 Edeon 6-24-53-18 0042714	0320 Edeon	639060 ELA-SHA-SHB	038 Hudson's Bay 0038 Hudson's Bay	Flow	2743.20	72-08-04

TABLE 1 - Continued

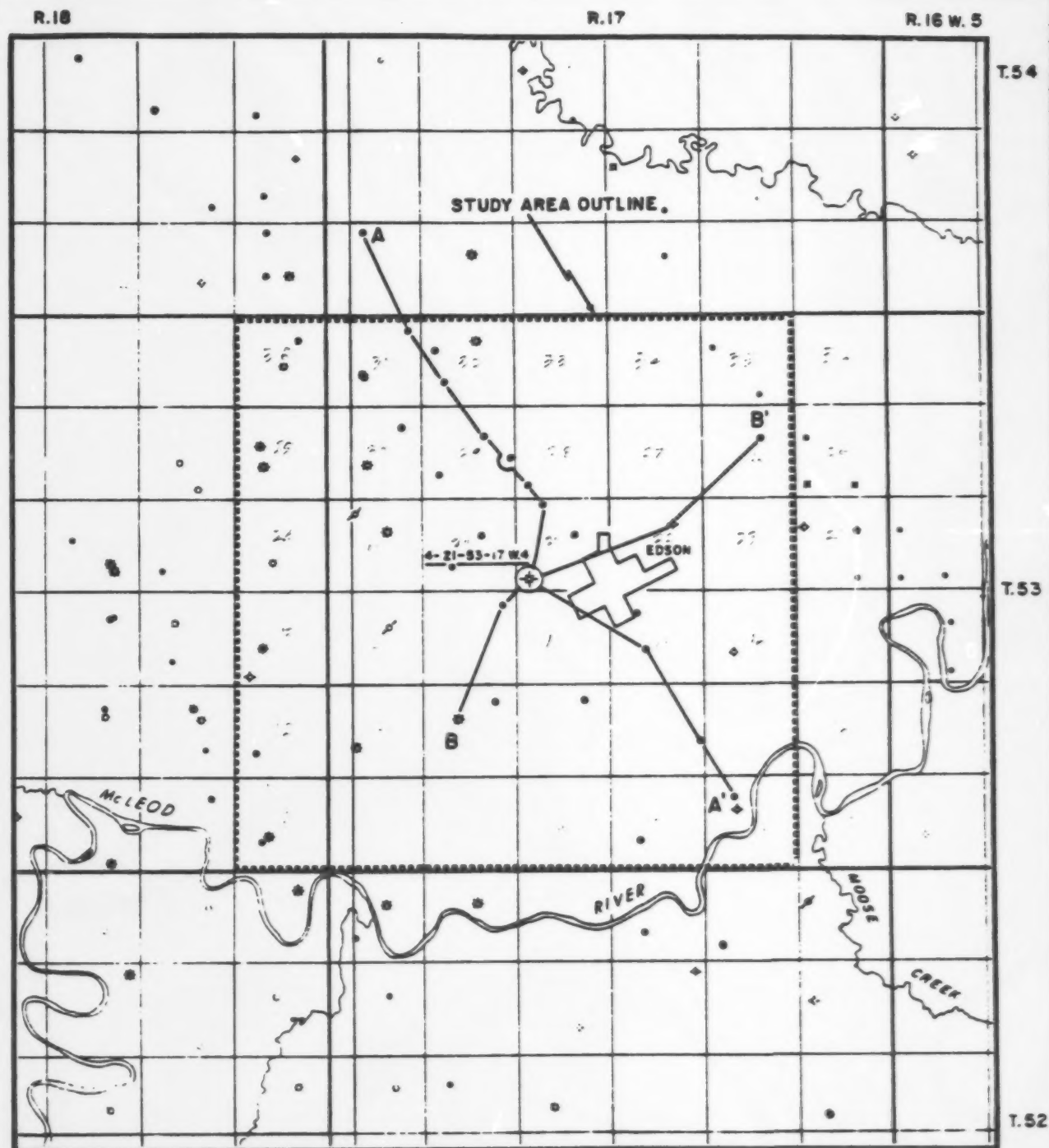
<u>Well I.D.</u>	<u>Well Name/ License No.</u>	<u>Field/ OS Area</u>	<u>Pool/ OS Deposit</u>	<u>Operator/ Licensee</u>	<u>Well Status</u>	<u>I.D.</u>	<u>FD Date</u>
00/06-25-053-10 W5/0	HB Gas Unit 1 Edeon 6-25-53-18 0050250	0320 Edeon	639060 ELA-SHA-SHB	038 0038 Hudson's Bay Hudson's Bay	Flow	2732.50	74-10-05
00/11-25-053-10 W5/0	HB Hamilton Edeon 11-25BY-53-18 0055606	0320 Edeon	326001 Gething A	038 0038 Hudson's Bay Hudson's Bay	Flow	2541.10	75-12-06
00/07-36-053-10 W5/0	HB Edeon 7-36BY-53-18 0064092	0320 Edeon	326001 Gething A	038 0038 Hudson's Bay Hudson's Bay	Flow	2542.00	77-07-01
00/10-36-053-10 W5/0	Gulf WestmIn Edeon 10-36-53-18 0091889	0320 Edeon	176020 Cardium T	002 0002 Gulf Can. Ltd. Gulf Can. Ltd.	CR-011 Flow	1960.00	81-09-17

TABLE 2
RESERVOIR DATA - WATER SOURCE

<u>Field and Pool</u>	<u>Porosity</u>	<u>Water Saturation</u>	<u>Water-In-Place</u>
	%	%	$\text{m}^3/10^4\text{m}^3$
<u>Edson, Alberta</u>			
Belly River 'A'	16	95	1,520
Belly River 'B'	15	95	1,425
Belly River 'C'	14	97	1,358
Belly River 'D'	13	100	1,300
Belly River 'E'	12	100	1,200

TABLE 3
ESTIMATES OF WATER RESOURCES

<u>Field and Pool</u>	<u>Production Area</u>	<u>Rock Volume</u>	<u>Water-In-Place</u>
	Hectares	10^4m^3	10^3m^3
<u>Edson, Alberta</u>			
Belly River 'A'	2,256	12,106	18,401
Belly River 'B'	777	2,253	3,210
Belly River 'C'	1,076	6,853	9,306
Belly River 'D'	1,779	7,434	9,664
Belly River 'E'	1,255	2,769	<u>3,323</u>
Total			<u>43,904</u>

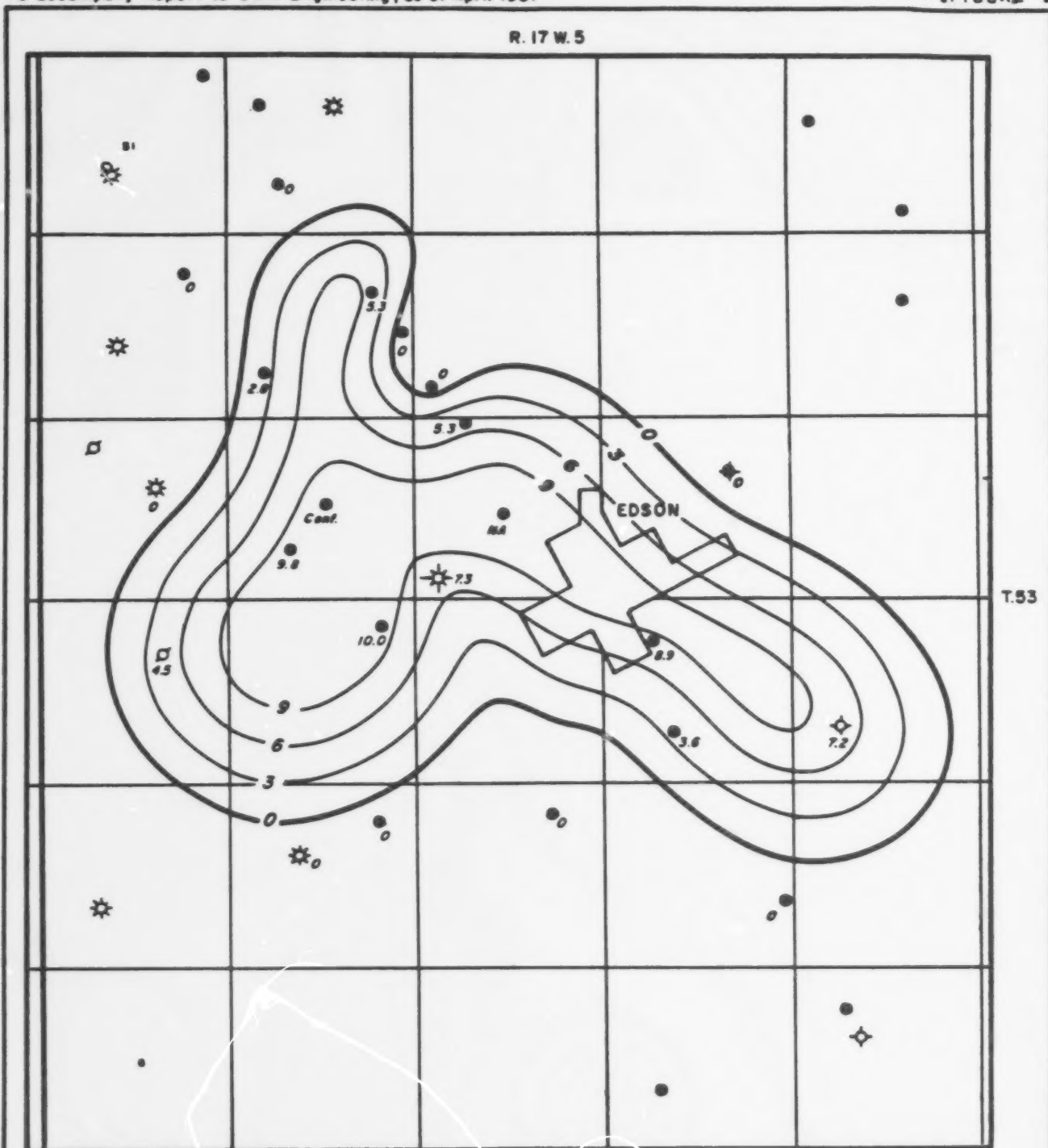
**LEGEND**

- Location
- Oil Well
- * Gas Well
- ⊠ Suspended Well
- ⊞ Service Well
- ⊛ Abandoned Well

A ——— A' Line of Cross Section

EDSON GEOTHERMAL PROJECT
LOCATION MAP
 SHOWING
STUDY AREA





LEGEND

- Location
- Oil Well
- ✱ Gas Well
- ◻ Suspended Well
- ✕ Service Well
- ◆ Abandoned Well
- Net Pay in Metres
- 5.6
- NA Not Available

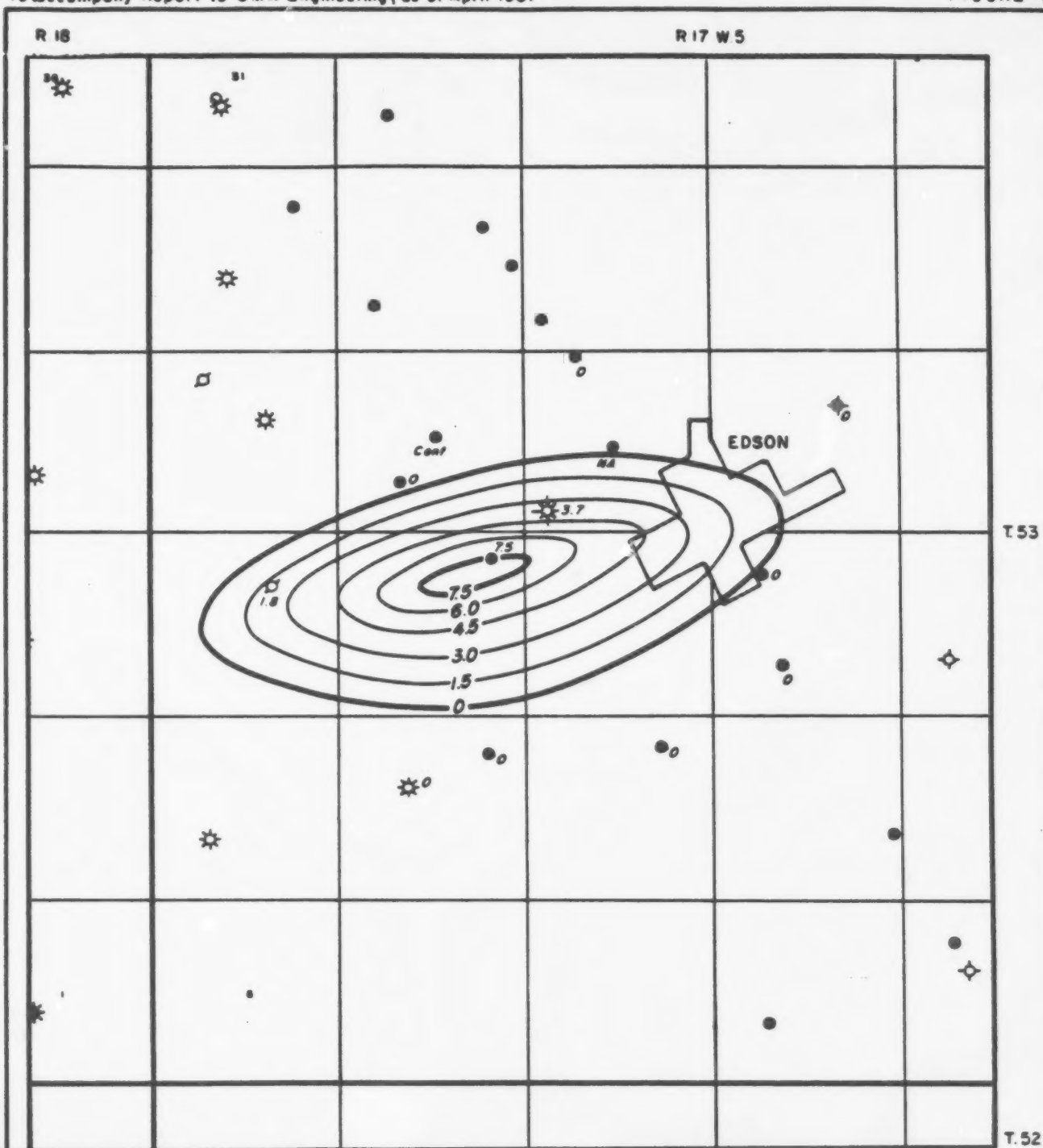
EDSON AREA

ISOPACH MAP

Net Pay - Geothermal Resource
Belly River 'A' Sandstone

Isopach Interval: 3 Metres



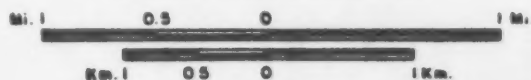
**LEGEND**

- Location
- Oil Well
- ✱ Gas Well
- ◻ Suspended Well
- ✕ Service Well
- ◆ Abandoned Well
- Net Pay in Metres
- 1.8
- NA Not Available

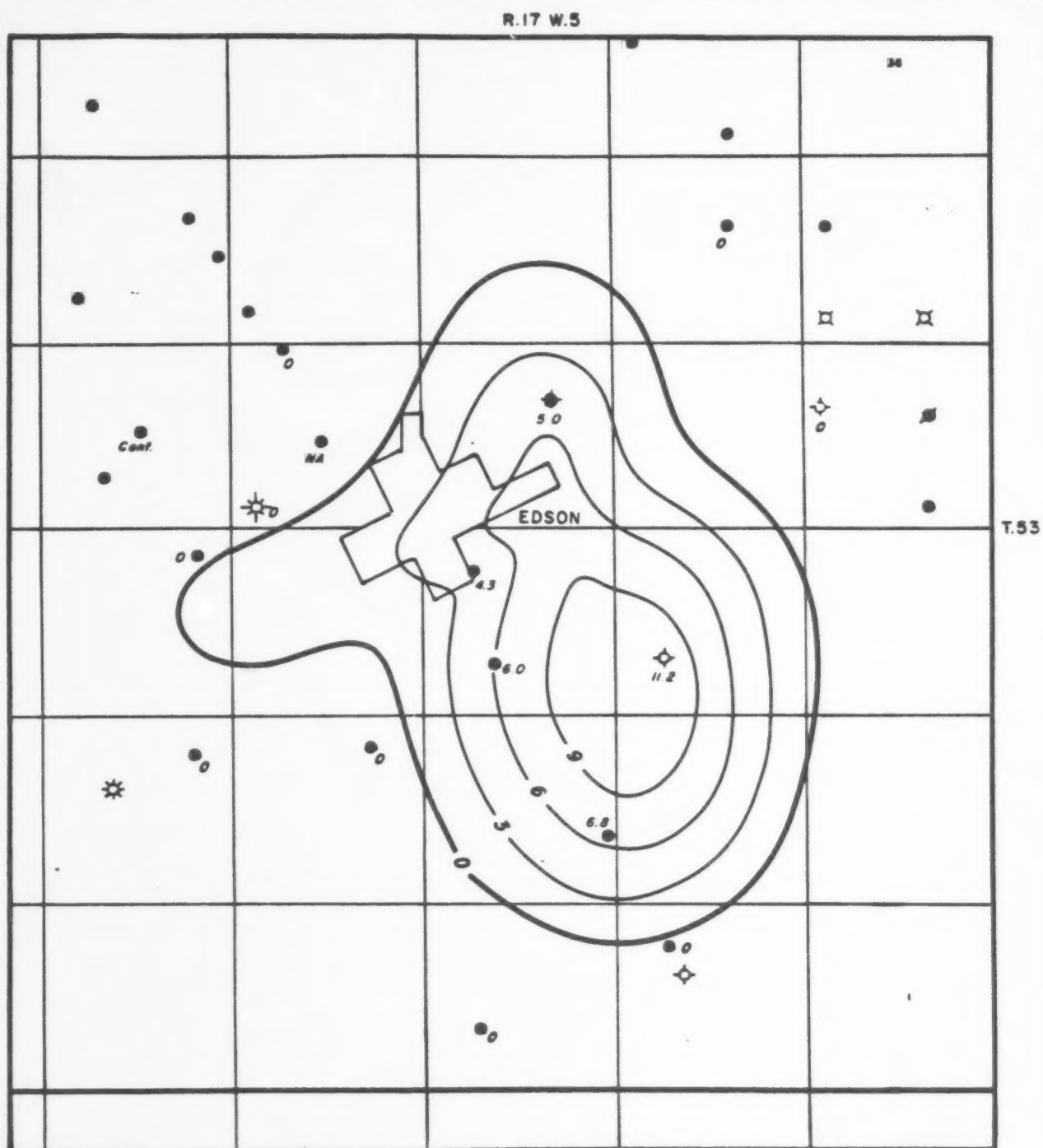
EDSON AREA**ISOPACH MAP**

Net Pay - Geothermal Resource
Belly River 'B' Sandstone

Isopach Interval: 1.5 Metres





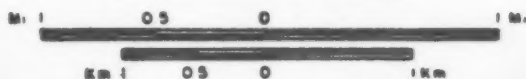
**LEGEND**

- Location
- Oil Well
- ★ Gas Well
- Suspended Well
- ⊠ Service Well
- ◇ Abandoned Well
- Net Pay in Metres
- 5.0
- NA Not Available

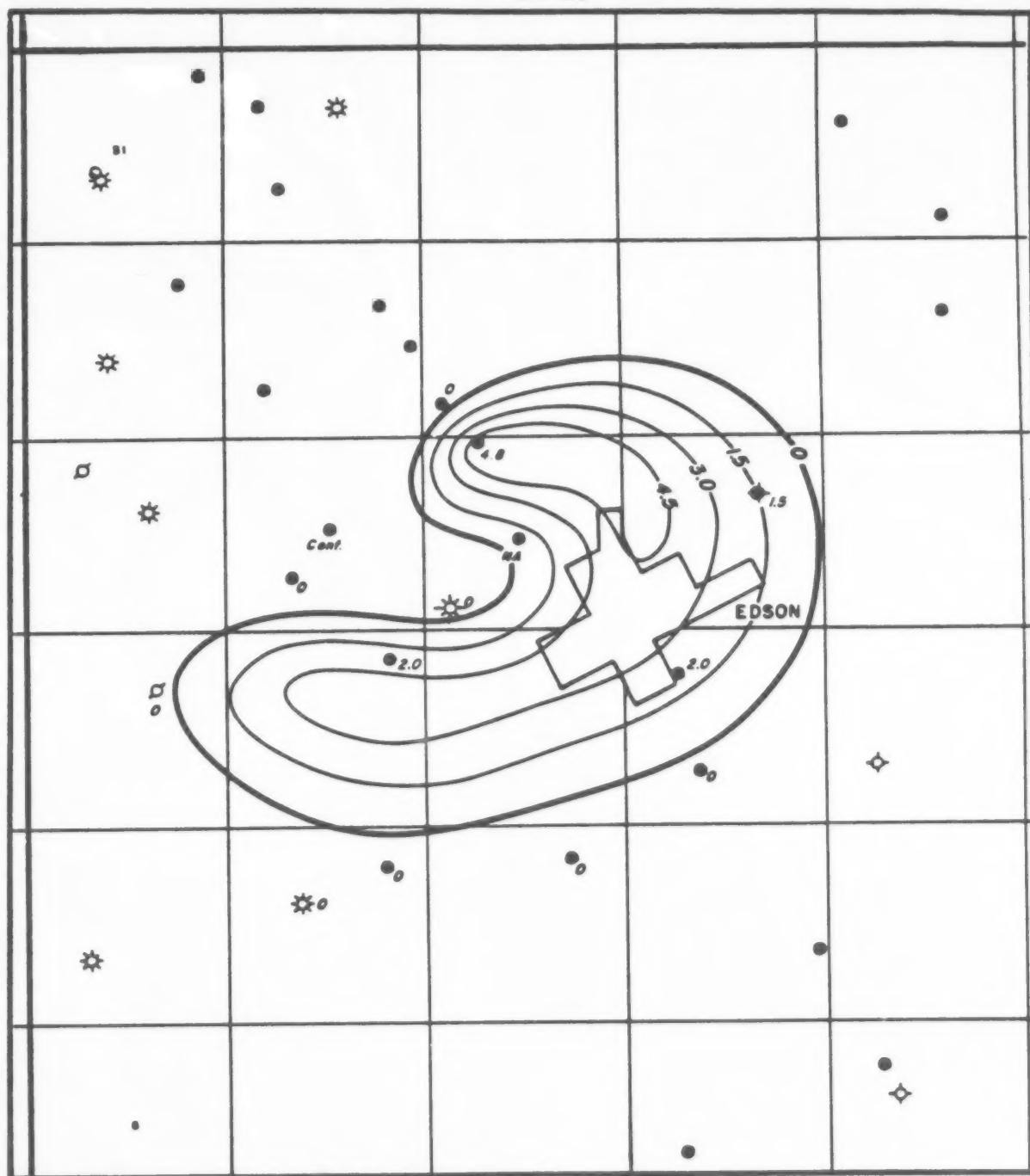
EDSON AREA**ISOPACH MAP**

Net Pay - Geothermal Resource
Belly River 'D' Sandstone

Isopach Interval: 3 Metres



R.17W.5

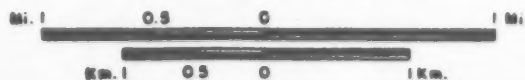
**LEGEND**

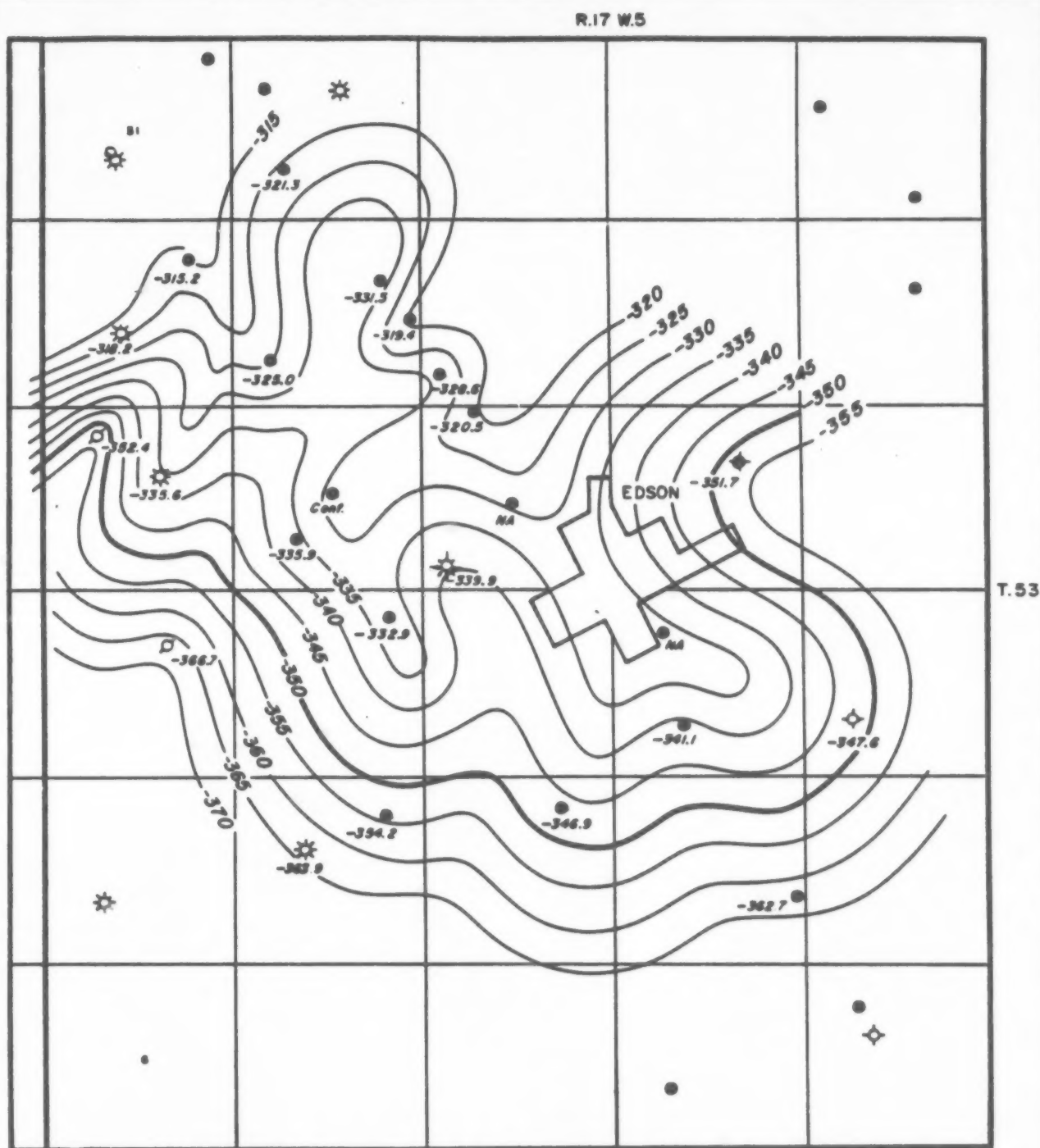
- Location
- Oil Well
- ★ Gas Well
- ◻ Suspended Well
- ✕ Service Well
- ◆ Abandoned Well
- Net Pay in Metres
- 2.0
- NA Not Available

EDSON AREA**ISOPACH MAP**

Net Pay - Geothermal Resource
Belly River Sandstone

Isopach Interval: 1.5 Metres



**LEGEND**

- Location
- Oil Well
- ★ Gas Well
- Suspended Well
- ⊗ Service Well
- ◆ Abandoned Well
- Top Porosity in Metres
- 315.0
- NA Not Available

EDSON AREA**STRUCTURE MAP**

Top Porosity
Belly River 'A' Sandstone

Contour Interval: 5 Metres





T.53

WORK MAP

Outline of Geothermal Resource Pools

- | | |
|---|----------------|
| □ | Location |
| ● | Oil Well |
| ✱ | Gas Well |
| ◻ | Suspended Well |
| ⌘ | Service Well |
| ⬠ | Abandoned Well |

- | | | |
|---|----------|--------------|
|  | A | Send Outline |
| | B | Send Outline |
|  | C | Send Outline |
| | D | Send Outline |
|  | E | Send Outline |

